(1) Publication number:

0 685 572 A2

℗

EUROPEAN PATENT APPLICATION

(1) Application number: 95103339.8

2 Date of filing: 08.03.95

(1) Int. Cl. 9: C23C 30/00, C23C 16/40, C23C 16/36

3 Priority: 31.05.94 JP 141100/94 31.05.94 JP 141101/94 31.05.94 JP 141122/94 31.05.94 JP 141123/94 15.06.94 JP 156842/94 15.06.94 JP 156843/94

15.06.94 JP 156844/94 15.06.94 JP 156845/94

19.09.94 JP 249945/94

- Date of publication of application: 06.12.95 Bulletin 95/49
- Designated Contracting States: DE FR GB IT
- 1 Applicant: MITSUBISHI MATERIALS CORPORATION 5-1, Otemachl 1-chome Chiyoda-ku, Tokyo (JP)
- 2 Inventor: Yoshimura, Hironori, c/o Tsukuba-Seisakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuukl-gun, Ibaraki-ken (JP) Inventor: Osada, Akira, c/o Tsukuba-Seisakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuukl-gun, Ibaraki-ken (JP)

Inventor: Onou, Kenichi, c/o Tsukuba-Selsakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuuki-gun. Ibaraki-ken (JP) Inventor: Oshika, Takatoshi, c/o Tsukuba-Selsakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuuki-gun, Ibaraki-ken (JP) Inventor: Sugawara, Jun, c/o Tsukuba-Selsakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuuki-gun, Ibaraki-ken (JP) Inventor: Hamaguchi, Yuuki, c/o Tsukuba-Selsakusho MITSUBISHI MATERIALS CORP., 1511, Ooaza Furumagi Ishige-machi, Yuuki-gun, Ibaraki-ken (JP)

- Representative: Hansen, Bernd, Dr. Dipl.-Chem. et al Hoffmann, Eitle & Partner, Patentanwälte, Arabellastrasse 4 D-81925 München (DE)
- Coated hard-alloy blade member.
- P A coated hard alloy blade member is disclosed which includes a substrate formed of a hard alloy of a WCbased cemented carbide or a TiCN-based cermet, and a hard coating deposited on the substrate. The hard coating includes an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form x or x + α wherein x > α . The resulting blade member is highly resistant to wear and fracturing, and possesses cutting ability of a higher level.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to coated hard alloy blade members or cutting tools having exceptional steel and cast Iron cutting ability for both continuous and interrupted cutting.

Background Art

5

10

35

Until now, the use of a coated cemented carbide cutting tool made by using either chemical vapor deposition or physical vapor deposition to apply a coating layer of an average thickness of 0.5-20 µm comprised of either multiple layers or a single layer of one or more of titanium carbide, titanium nitride, titanium carbonitride, titanium oxycarbide titanium oxycarbonitride, and aluminum oxide (hereafter indicated by TiC, TiN, TiCN, TiCN, and Al₂O₃) onto a WC-based cemented carbide substrate for cutting steel or cast iron has been widely recognized.

The most important technological advance that led to the wide usage of the above-mentioned coated cemented carbide cutting tool was, as described in Japanese Patent Application No. 52-46347 and Japanese Patent Application No. 51-27171, the development of an exceptionally tough substrate wherein the surface layer of a WC-based cemented carbide substrate included a lot of Co, a binder metal, in comparison with the interior, whereby the fracture resistance of the coated cemented carbide cutting tool rapidly improved.

In addition, as disclosed in Japanese Patent Application No. 52-156303 and Japanese Patent Application No. 54-83745, the confirmation that, by sintering the WC-based cemented carbide containing nitrogen in a denitrifying atmosphere such as a vacuum, the surface layer of the WC-based cemented carbide substrate can be made from WC-Co which does not include a hard dispersed phase having a B-1 type crystal structure, whereby it is possible to cheaply produce WC-based cemented carbide having more Co in its surface layer than in the interior, was also important.

Concerning the advancement of the coating layer, coated cemented carbides having coating layers wherein the X-ray diffraction peaks of the Ti compounds such as TiC, TiN, and TiCN have a strong (200) orientation and the Al_2O_3 has an α -type crystal structure such as described in Japanese Patent Application No. 61-231416 and coated cemented carbides having coating layers wherein the X-ray diffraction peaks of the Ti compounds such as TiC, TiN, and TiCN have a strong (220) orientation and the Al_2O_3 has a x-type crystal structure such as described in Japanese Patent Application No. 62-29263 have little variation in the tool life.

Furthermore, Japanese Patent Application No. 2-156663 shows that a coated cemented carbide having a coating layer wherein the TIC has a strong (111) orientation and the Al_2O_3 is of the x-type has the features that there is less spalling of the coating layer and has a long life.

However, since the Ti compounds such as TiC of Japanese Patent Application No. 61-231416, Japanese Patent Application No. 62-29263, and Japanese Patent Application No. 2-156663 are coated by the normal CVD method, the crystal structure is in a granular form identical to the coating layers of the past, and the cutting ability was not always satisfactory.

Additionally, Japanese Patent Application No. 50-16171 discloses that coating is possible with the use of organic gas for a portion of the reaction gas, at a relatively low temperature. In this patent, the crystal structure of the coating layer is not described, and furthermore, the crystal structure may have a granular form, or the crystals may grow in one direction (elongated crystals) depending on the coating conditions. Moreover, in the references given in this patent, the coating layer is made up of only TiCN, and $Al_2\,O_3$ is not disclosed. Additionally, this TiCN had a low bonding strength with the substrate.

SUMMARY OF THE INVENTION

50

In recent years cutting technology has shown remarkable progress towards unmanned, high speed processes. Therefore, tools which are highly resistant to wear and fracturing are required. Consequently, the present inventors conducted research to develop a coated cemented carbide cutting tool having cutting ability of a higher level.

It was discovered that by coating the surface of a WC-based cemented carbide substrate and a TiCN-based cermet substrate with TiCN having crystals growing in one direction (elongated crystals) as an inner layer, and coating with Al_2O_3 having a crystal structure x or $x + \alpha$ wherein $x > \alpha$ as an outer layer, remarkable steel and cast iron cutting ability was shown for both continuous cutting and interrupted cutting.

Thus, the coated hard alloy blade member in accordance with the present invention comprises a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, the hard coating including an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al₂O₃ having a crystal form x or $x + \alpha$ wherein $x > \alpha$.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a photograph of a coated cemented carbide blade member in accordance with the present invention as taken by a scanning electron microscope.

DETAILED DESCRIPTION OF THE INVENTION

The coated hard alloy blade member or cutting tool in accordance with the present invention will now be described in detail.

As mentioned before, the coated hard alloy blade member in accordance with the present invention comprises a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, the hard coating including an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form x or $x + \alpha$ wherein $x > \alpha$.

In order to practicalize the present invention, it is first necessary to coat the substrate with elongated crystal TiCN having high bonding strength. If the conditions are such that, for example, during the coating of the TiCN, the percentages of the respective volumes are: TiCl4: 1-10%, CH₃CN: 0.1-5%, N₂: 0-35%, H₂: the rest, the reaction temperature is 800-950 °C, the pressure is 30-500 Torr, and furthermore, the CH₃CN gas is decreased to 0.01-0.1% at the beginning of the coating as a first coating reaction for 1-120 minutes, then the CH₃CN gas is increased to 0.1-1% as a second coating reaction, then elongated crystal TiCN having high bonding strength can be obtained. The thickness of the TiCN coating layer should preferably be 1-20 μm. This is because at less than 1 μm the wear resistance worsens, and at more than 20 μm the fracture resistance worsens.

Furthermore, during the coating of the TiCN, if the reaction temperature or the amount of CH₂CN is Increased, the (200) plane component of the X-ray diffraction pattern of the TiCN becomes weaker than the (111) and (220) plane components, the bonding strength with the Al_2O_3 in the upper layer which has x as its main form increases, and the wear resistance goes up.

Next, Al_2O_3 of x form or $x + \alpha$ form wherein form $x > \alpha$ is coated. For coating Al_2O_3 which has x as its principal form, the conditions should be such that, for example, the reaction gas is made up of the following volume percentages in the first 1-120 minutes: $AlCl_3$: 1-20%, HCl: 1-20% and/or H_2S : 0.05-5% as needed, and H_2 : the rest, and a first reaction be performed, then afterwards, a second reaction is performed in which $AlCl_3$: 1-20%, CO_2 : 0.5-30%, HCl: 1-20% and/or H_2S : 0.05-5% as needed, and H_2 : the rest, with the conditions of a reaction temperature of 850-1000 °C and pressure of 30-500 Torr.

The thickness of this A½ O₂ coating layer should preferably be 0.1-10 μm. At less than 0.1 μm the wear resistance worsens, while at over 10 μm the fracturing resistance worsens.

The combined thickness of the first TiCN layer and the second Al₂O₃ layer should preferably be 2-30 μm.

The K ratio of the $x + \alpha Al_2O_3$ of the present invention uses a peak from Cu- $x\alpha$ X-ray diffraction, and is determined the following equation, wherein if $x > \alpha$ then the x ratio is over 50%.

$$I_{\kappa 2.79} + I_{\kappa 1.43}$$
 $\kappa \text{ ratio (\%)} = ---- \times 100$

$$I_{\kappa 2.79} + I_{\kappa 1.43} + I_{\alpha 2.085} + I_{\alpha 1.601}$$

wherein

55

The height of the X-ray diffraction peak for ASTM No. 4-0878 with a plane index spacing of

I_{x1.49}: The height of the X-ray diffraction peak for ASTM No. 4-0878 with a plane index spacing of d = 1.43

I_{e2.085}: The height of the X-ray diffraction peak for ASTM No. 10-173 with a plane index spacing of

d = 2.085 (the (113) plane)

l_{a1.601}: The height of the X-ray diffraction peak for ASTM No. 10-173 with a plane index spacing of

d = 1.601 (the (116) plane)

As further modified embodiments of the present invention, the following are included.

- (1) As an outermost layer, either one or both of TiN or TiCN may be coated on the outer Al_2O_3 layer. The reason for this coating layer is to discriminate between areas of use, and a thickness of 0.1-2 μ m is preferable.
- (2) As an innermost layer, either one or more of TiN, TiC, or TiCN (granular form) may be coated underneath the inner TiCN layer. By coating with this innermost layer, the bonding strength of the elongated crystal TiCN improves and the wear resistance improves. The most preferable thickness for this coating is $0.1-5~\mu m$.
- (3) Between the inner TiCN layer and the outer Al_2O_3 layer, either one or more of TiN, TiC, or TiCN (granular form) may be coated as a first intermediate layer. This first intermediate layer improves the wear resistance during low speed cutting. However, during high speed cutting, it worsens the wear resistance. The most preferable thickness for this first intermediate layer is 1-7 μ m.
- (4) Between the inner TiCN layer and the outer Al_2O_3 layer, either one or both of TiCO, TiCNO is coated as a second intermediate layer. This second intermediate layer increases the bonding strength between the elongated crystal TiCN and the x or $x + \alpha$ form Al_2O_3 . The most preferable thickness of this second intermediate layer is 0. 1-2 μ m.
- (5) It is possible to combine the above-mentioned (1)-(4) as appropriate.
- (6) The inner layer coated with elongated crystal TICN may be divided by one or more TIN layers to define a divided TICN layer. This divided TICN layer is less susceptible to chipping, and the fracture resistance improves.
- (7) With the divided elongated TiCN described above and the κ or $\kappa + \alpha$ form Al_2O_3 , it is possible to coat with an outermost layer of one or both of TiN or TiCN as in (1) above, coat with an innermost layer of one or more of TiN, TiC, or TiCN as in (2) above, coat with a first intermediate layer of one or more of TiC, TiN, or TiCN as in (3) above, coat with a second intermediate layer of one or both of TiCO or TiCNO as in (4) above, or to take a combination of them.
- (8) The most preferable composition of the WC-based cemented carbide substrate is, by the percentage of weight, as follows:

Co: 4-12%	Ti: 0-7%	Ta: 0-7%
Nb: 0-4%	Cr: 0-2%	
N: 0-1%	W and C: the rest	

Unavoidable impurities such as O, Fe, Ni, and Mo are also included.

- (9) For the WC-based cemented carbide of the present invention, for lathe turning of steel, it is preferable that the cemented carbide be such that the amount of Co or Co + Cr in the surface portion (the highest value from the surface to within 100 μm) be 1.5 to 5 times the amount in the interior (1 mm from the surface), and for lathe turning of cast iron, it is preferable that there is no enrichment of the Co or Co + Cr, and that the amount of Co or Co + Cr be small. Furthermore, in the case of steel milling, cemented carbide in which there has been no enrichment of the Co or Co + Cr, and the amount of Co or Co + Cr is large, is preferable.
- (10) The most preferable composition of the TiCN-based cermet substrate is, by the percentage of weight, as follows:

Co: 2-14%	Ni: 2-12%	Ta: 2-20%
Nb: 0.1-10%	W: 5-30%	Mo: 5-20%
N: 2-8%	Ti and C: the rest	
Cr, V, Zr, Hf: 0-5%		

Unavoidable impurities such as O and Fe are included.

(11) In the TICN-based cermet of the present invention, the substrate surface layer (the largest value within 100 µm of the surface) should be 5% or more harder than the interior (1 mm from the surface) or there should be no difference between the hardnesses of the surface layer and the interior.

4

50

55

45

5

10

15

20

25

30

35

The present invention will be explained in more detail by way of the following examples.

EXAMPLE 1

As the raw materials, medium grain WC powder having an average particle size of 3 μm, 5 μm coarse grain WC powder, 1.5 μm (Ti, W)C (by weight ratio, TiC/WC = 30/70) powder 1.2 μm (Ti, W)(C, N) (TiC/TiN/WC = 24/20/56) powder, 1.5 μm Ti(C, N) (TiC/TiN = 50/50) powder, 1.6 μm (Ta, Nb)C (TaC/NbC=90/10) powder, 1.8 μm TaC powder, 1.1 μm Mo₂C powder, 1.7 μm ZrC powder, 1.8 μm Cr₃C₂ powder, 2.0 μm Ni powder, 2.2 μm NiAl (Al: 31% by weight) powder, and 1.2 μm Co powder were prepared, then these raw material powders were blended in the compositions shown in Table 1 and wetmixed in a ball mill for 72 hours. After drying, they were press-shaped into green compacts of the form of ISO CNMG 120408 (cemented carbide substrates A-D, cermet substrates F-G) and SEEN 42 AFTN 1 (cemented carbide substrates E and E'), then these green compacts were sintered under the conditions described in Table 1, thus resulting in the production of cemented carbide substrates A-E, E' and cermet substrates F-G.

Experimental values taken at over 1 mm from the surface of the sintered compacts of the cemented carbide substrates A-E, E' and the cermet substrates F-G are as shown in Table 2.

Furthermore, in the case of the above cemented carbide substrate B, after maintenance in an atmosphere of CH₄ gas at 100 torr and a temperature of 1400 °C for 1 hour, a gradually cooling carburizing procedure was run, then, by removing the carbon and Co attached to the substrate surface using acid and barrel polishing, a Co-rich region 40 µm deep was formed in the substrate surface layer wherein, at a position 10 µm from the surface the maximum Co content was 15% by weight.

Additionally, in the case of cemented carbide substrates A and D above, while sintered, a Co-rich region 20 μ m deep was formed wherein, at a position 15 μ m from the surface, the maximum Co content was 11% and 9% by weight, respectively, and in the remaining cemented carbide substrates C, E and E', no Co-rich region was formed, and they had similar compositions over their entirety.

In the above cermet substrates F and G, in the sintered state, a surface layer harder than the interior existed. The hardnesses at the surface and 1 mm below the surface for the cermet substrates F and G are shown in Table 2.

Next, after honing the surfaces of the cemented carbide substrates A-E, E' and cermet substrates F and G, by forming coating layers under the special coating conditions shown in Tables 3(a) and 3(b) and having the compositions, crystal structures, orientation of TICN (shown, starting from the left, in the order of the intensity of the corresponding X-ray diffraction peak) and average thicknesses shown in Table 4 by using a chemical vapor deposition apparatus, the coated cemented carbide cutting tools of the present invention 1
12 and 15-26, the coated cermet cutting tools of the present invention 13, 14, 27, and 28, the coated cemented carbide cutting tools of the prior art 1-12 and 15-26, and the coated cermet cutting tools 13, 14, 27, and 28 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 1-10 and 15-24, and the coated cemented carbide cutting tools of the prior art 1-10 and 15-24, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar Cutting Speed: 270 m/min Feed: 0.25 mm/rev

Depth of Cut: 2 mm Cutting Time: 30 min

45

50

in which a determination was made whether or not the cutting failed due to tears made in the workpiece because of chipping of the cutting blade or spalling of the coating layer. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 250 m/min Feed: 0.25 mm/rev Depth of Cut: 1.5 mm

Cutting Time: 40 min

In which a determination was made whether or not the cutting failed due to trouble such as fracturing or chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

For the coated cemented carbide cutting tools of the present invention 11, 12, 25 and 26, and the coated cemented carbide cutting tools of the prior art 11, 12, 25 and 26, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block

Cutting Speed: 250 m/min Feed: 0.35 mm/tooth Depth of Cut: 2.5 mm Cutting Time: 40 min

5

15

25

35

50

65

in which a determination was made whether or not the milling failed due to trouble such as chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

For the coated cermet cutting tools of the present invention 13, 14, 27 and 28, and the coated cermet cutting tools of the prior art 13, 14, 27 and 28, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar

Cutting Speed: 320 m/min Feed: 0.25 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

in which a determination was made whether or not the cutting failed due to chipping or fracturing of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 300 m/min

Feed: 0.20 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

In which a determination was made whether or not the cutting falled due to trouble such as chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

The results of the above tests are shown in Tables 4-7. As is able to be seen from Tables 4-7, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 2

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 8 and 9, the coated cemented carbide cutting tools of the present invention 29-40, the coated cermet cutting tools of the present invention 41 and 42, the coated cermeted carbide cutting tools of the prior art 29-40, and the coated cermet cutting tools 41 and 42 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 29-38, and the coated cemented carbide cutting tools of the prior art 29-38, a mild steel continuous cutting test was performed under the following conditions.

Workpiece: mild steel round bar Cutting Speed: 250 m/min

Feed: 0.27 mm/rev Depth of Cut: 2 mm Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mlid steel round bar with groove

Cutting Speed: 230 m/min Feed: 0.27 mm/rev

Depth of Cut: 1.5 mm Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 39 and 40, and the coated cemented carbide cutting tools of the prior art 39 and 40, a mild steel milling test was performed under the following conditions.

Workpiece: mild steel square block

Cutting Speed: 230 m/min Feed: 0.37 mm/tooth Depth of Cut: 2.5 mm Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 41 and 42, and the coated cermet cutting tools of the prior art 41 and 42, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar

Cutting Speed: 300 m/min

Feed: 0.27 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 280 m/min Feed: 0.22 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 8, 9(a) and 9(b). As is able to be seen from Tables 8, 9(a) and 9(b), all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 3

15

Using the same comented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thickness shown in Tables 10-13, the coated cemented carbide cutting tools of the present invention 43-54 and 57-68, the coated cermet cutting tools of the present invention 55, 56, 69 and 70, the coated cemented carbide cutting tools of the prior art 43-54 and 57-68, and the coated cermet cutting tools 55, 56, 69 and 70 of the prior art were produced. Figure 1 shows a photograph of the surface layer of the coated cemented carbide cutting tool of the present invention as taken by a scanning electron microscope.

Then, for the coated cemented carbide cutting tools of the present invention 43-52 and 57-66, and the coated cemented carbide cutting tools of the prior art 43-52 and 57-66, a mild steel continuous cutting test was performed under the following conditions.

Workpiece: mild steel round bar

Cutting Speed: 280 m/min Feed: 0.23 mm/rev Depth of Cut: 2 mm Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 260 m/min Feed: 0.23 mm/rev Depth of Cut: 1.5 mm Cutting Time: 40 min

55

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 53, 54, 67 and 68, and the coated cemented carbide cutting tools of the prior art 53, 54, 67 and 68, a mild steel milling test was performed under the following conditions.

Workpiece: mild steel square block

Cutting Speed: 260 m/min Feed: 0.33 mm/tooth Depth of Cut: 2.5 mm Cutting Time: 40 min

5

10

15

20

30

45

50

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 55, 56, 69 and 70, and the coated cermet cutting tools of the prior art 55, 56, 69 and 70, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar Cutting Speed: 330 m/min Feed: 0.23 mm/rev

Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 310 m/min Feed: 0.18 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 10-13. As is able to be seen from Tables 10-13, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 4

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 14-17, the coated cemented carbide cutting tools of the present invention 71-82 and 85-96, the coated cermet cutting tools of the present invention 83, 84, 97 and 98, the coated cemented carbide cutting tools of the prior art 71-82 and 85-96, and the coated cermet cutting tools 83, 84, 97 and 98 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 71-80 and 85-94, and the coated cemented carbide cutting tools of the prior art 71-80 and 85-94, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar Cutting Speed: 260 m/min Feed: 0.26 mm/rev

Depth of Cut: 2 mm Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 240 m/min Feed: 0.26 mm/rev Depth of Cut: 1.5 mm

Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 81, 82, 95 and 96, and the coated cemented carbide cutting tools of the prior art 81, 82, 95 and 96, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block

Cutting Speed: 240 m/min Feed: 0.36 mm/tooth Depth of Cut: 2.5 mm Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 83, 84, 97 and 98, and the coated cermet cutting tools of the prior art 83, 84, 97 and 98, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar Cutting Speed: 310 m/min Feed: 0.26 mm/rev

Depth of Cut: 1 mm Cutting Time: 20 min

10

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 290 m/min Feed: 0.21 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 14-17. As is able to be seen from Tables 14-17, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 5

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 18-21, the coated cemented carbide cutting tools of the present invention 99-112 and 122-126, the coated cermet cutting tools of the present Invention 113-121, the coated cemented carbide cutting tools of the prior art 99-112 and 122-126, and the coated cermet cutting tools 113-121 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 99-112, and the coated cemented carbide cutting tools of the prior art 99-112, a mild steel high-feed continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar

Cutting Speed: 210 m/min

Feed: 0.38 mm/rev

40

45

55

Depth of Cut: 2 mm Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, a deep cut interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar

Cutting Speed: 210 m/min Feed: 0.23 mm/rev Depth of Cut: 4 mm Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 122-126, and the coated cemented carbide cutting tools of the prior art 122-126, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block

Cutting Speed: 260 m/min Feed: 0.33 mm/tooth Depth of Cut: 3 mm

Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 113-121, and the coated cermet cutting tools of the prior art 113-121, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar

Cutting Speed: 340 m/min Feed: 0.22 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

5

15

25

30

35

40

45

50

55

10 and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove

Cutting Speed: 320 m/min Feed: 0.17 mm/rev Depth of Cut: 1 mm Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 18-21. As is able to be seen from Tables 18-21, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

TABLE 1

TABLE

					,
		Communition of Sintered Rody (a by weight)	нага	Hardness	
			Interior (MRA)	Surface (HRA)	
	<	A 6.1 Co - 2.1 Ti - 3.4 Ta - 0.4 Nb - Rest (W + C)	90.5	•	
	<u></u>	5.2 Co - 1.2 Ti - 4.2 Ta - 0.4 Nb - Rest (W + C)	91.0	-	
	٥	9.0 Co - 1.9 Ti - 4.3 Ta - 0.4 ND - Rest (W + C)	80.3	•	
Cemented Carbide Substrate	۵	5.2 Co - 1.7 Tl - 2.5 Ta - 0.3 Mb - Rest (W + C)	91.1	•	
	ы	9.8 Co - 1.7 Ta - 0.2 Nb - Rest (M + C)	89.7	•	
	Ñ	9.8 Co - 0.6 Cr - Rest (M + C)	8.68	•	
Cermet	Es.	F 9.4 Ta - 12.2 W - 9.4 Mo - 0.4 Zr - 7.9 Co - 5.1 Ni - 0.1 Al - 3.8 N - Rest (Ti + C)	91.7	92.2	
Substrate	υ	9.5 Ta - 0.9 Nb - 8.5 W - 8.5 Mo - 7.1 Co - 7.0 Ni - 6.8 N - Rest (Ti + C)	91.6	92.6	

TABLE 3 (a)

(Coating Conditions)

5	10000000				
	Composition	X-ray Orientation	Gas Composition (% by volume)	Temperature	Pressure (Torr)
10	Innermost Layer Granular TiC		TiCl4:2, CH4:5, H2:Rest	1020	50
	Innermost Layer Granular TiN		TiCl4:2, N2:25, H2:Rest	920	50
15	Innermost Layer Granular TiCN		TiCl ₄ :2, CH ₄ :4, N ₂ :20, H ₂ :Rest	1020	50
	Inner Layer Elongated TiCN	(1111 (220) (200)	First Reaction - TiCl ₄ :2, CH ₃ CN:0.05, N ₂ :20, H ₂ :Rest Second Reaction - TiCl ₄ :2, CH ₃ CN:0.6, N ₂ :20, H ₂ :Rest	860	50
20	Inner Layer Elongated TiCN	(220) (111) (200)	Pirst Reaction - TiCl ₄ :2, CH ₂ CN:0.05, N ₂ :20, H ₂ :Rest Second Reaction - TiCl ₄ :2, CH ₂ CN:0.6, N ₂ :20, H ₂ :Rest	900	50
	Inner Layer Elongated TiCN	(111) (200) (220)	Pirst Reaction - TiCl ₄ :2, CH ₃ CN:0.05, N ₂ :20, H ₂ :Rest Second Reaction - TiCl ₄ :2, CH ₃ CN:0.3, N ₂ :20, H ₂ :Rest	860	50
25	Inner Layer Blongated TiCN	(220) (200) (111)	First Reaction - TiCl ₄ :4, CH ₃ CN:0.05, N ₂ :20, H ₂ :Rest Second Reaction - TiCl ₄ :4, CH ₃ CN:0.3, N ₂ :20, H ₂ :Rest	900	50
	Inner Layer Granular TiCM	(111) (200) (220)	TiCl4:4, CH4:6, N2:2, H2:Rest	1050	500
30	Inner Layer Granular TiCN	(220) (200) (111)	TiCl ₄ :4, CH ₄ :4, N ₂ :2, H ₂ :Rest	1050	500
	Inner Layer Granular TiCN	(200) (220) (111)	TiCl ₄ :4, CH ₄ :2, N ₂ :2, H ₂ :Rest	1000	100
35	Divided Layer Granular_TiN		TiCl ₄ :2, N ₂ :25, H ₂ :Rest	900	200
	Divided Layer Granular Tin		TiCl ₄ :2, N ₂ :25, H ₂ :Rest	860	200
40	Pirst Incermediate Layer Granular Tic		TiCl4:2, CH4:5, H2:Rest	1020	50
	Pirst Intermediate Layer Granular TiCN		TiCl4:2, CH4:4. N2:2D. H2:Rest	1020	\$0
45	Second Intermediate Layer Granular TiCO		TiCl ₄ :4, CO:6, H ₂ :Rest	980	50
50	Second Intermediate Layer Granular TICNO		TiCl4:4, CH4:2, N2:1.5, CO2:0.5, M2:Rest	1000	50

TABLE 3 (b)

5	Composition	X-ray Orientation	Gas Composition (% capacity)	Temperature (°C)	Pressure (Torr)
	Outer Layer Al ₂ O ₃	1001K	Pirst Reaction - AlCl3:3%, H2:Rest Second Reaction - AlCl3:3%, CO2:5%, H2S:0.3, H2:Rest	970	50
10	Outer Layer Al ₂ O ₃	94 % K	First Reaction - AlClj:3%, H2:Rest Second Reaction - AlClj:3%, CO2:5%, H2:Rest	970	50
	Outer Layer Al ₂ O ₃	85 % K	First Reaction - AlClj:3%, H2:Rest Second Reaction - AlClj:3%, CO2:6%, H2S:0.2, H2:Rest	980	50
15	Outer Layer Al ₂ O ₃	73 % K	First Reaction - AlCl ₃ :3%, H ₂ :Rest Second Reaction - AlCl ₃ :3%, CO ₂ :6%, H ₂ :Rest	980	\$0
	Outer Layer Al ₂ O ₃	62 % K	Pirst Reaction - AlCl3:3%, H2:Rest Second Reaction - AlCl3:3%, CO2:7%, H2S:0.2, H2:Rest	990	50
20	Outer Layer	558K	Pirst Reaction - AlCl3:3%, H2:Rest Second Reaction - AlCl3:3%, CO2:8%, H2:Rest	1000	50
	Outer Layer	40%×	First Reaction - AlClj:3%, H ₂ S:0.05, H ₂ :Rest Second Reaction - AlClj:3%, CO ₂ :9%, H ₂ S:0.1, H ₂ :Rest	1010	50
25	Outer Layer	100%α	AlCl3:38, CO2:108, H2:Rest	1020	100
	Outermost Layer Granular TiN		TiCl4:2, N2:30, H2:Rest	1020	200
30	Outermost Layer Granular TiN		TiCl4:2, CH4:4, N2:20, H2:Rest	1020	200

					Hard o	Hard Coating Layer				Plank Wear	Wear
ayt.		Substrate Symbol		Inner Layer	1	Outer Layer	ayer	Outermost Layer	. Layer	(ww)	(u
·			Composition	Crystal	Orientation	Composition	Crystal Structure	Composition	Crystel Structure	Continuous	Interrupted Cutting
	-	4	Tich(8.4)	Elongated	(111) (220) (200)	A1203 (2.2)	K: 944	TIN(0.5)	Granular	6.17	0.26
	~	<	TLCN(5.5)	Plongated Growth	(220) (111) (200)	A1203 (6.2)	K:851			0.19	0.28
	^	¥	TiCN(11.4)	Elongated	(111) (220) (200)	A1203(1.8)	K: 1004	Tich- Tin(0.7)	Granular	0.19	16.0
	•	8	T(CN(8.2)	Elongated Growth	(111) (200) (220)	A1203 (2.1)	K: 1008	TIN(0.4)	Granular	0.17	0.31
Coated	s	8	Tich(5.1)	Elongated Growth	(111) (220) (200)	A1203 (5.2)	K:738			0.21	0.26
Cementing	9	U	TiCN(10.2)	Elongated Growth	(220) (111) (200)	A1203 (1.2)	K:551	TÍN(0.3)	Granular	0.22	16.0
Carbide	-	v	TiCN(5.4)	Elongated Growth	(220) (200) (111)	A1203 (0.9)	x:621	TIN(0.6)	Granular	0.26	ÞE ' 0
Cutting	ω_	٥	Ticn(6.4)	Blongated Growth	(111) (220) (200)	(L'5) COZTA	K:734	Tin(0.2)	Granular	0.16	0.26
1001	٥	۵	TICN(3.7)	Blongated Growth	(220) (111) (200)	A1203 (8.2)	K: 62%			0.17	0.30
of the	20	C	Ticn(7.9)	Elongated Growth	(111) (220) (200)	A1203 (2.5)	K:1008			0.18	0.26
Invention	11	မ	TiCN(4.2)	Slongated Growth	(220) (111) (200)	A1203 (0.5)	K: 1001			0.17	(Hilling)
	12	ù	Ticn(4.0)	Elongated Growth	(111) (220) (111)	A1203 (0.4)	K:941	TIN(0.3)	Granular	61.0	(Hilling)
	2	£	TiCN(4.6)	Elongated Growth	(220) (111) (200)	A1203 (0.4)	K: 1001	Tin(0.4)	Granular	0.16	0.29
	ž	U	TiCN(3.2)	Elongated	(111) (220) (111)	A1203 (0.8)	X:948	TiN(0.2)	Granular	0.16	0.27

TABLE 5

					Hard C	Hard Coating Layer				Flank Wear	West	
Type		Substrate		Inner Layer	35	Outer Layer	ayer	Outermost Layer	Layer	(m)	(a	
		- Comple	Composition	Crystal	Orientation	Composition	Crystel Structure	Composition	Crystal Structure	Continuous	Interrupted Cutting	
	-	۷	TiCH(8.5)	Granular	(111) (200) (111)	A1203 (2.0)	a: 1001	TIN(0.5)	Granular	0.47 (Chipping)	0.60 (Chipping)	
	~	<	Tich(5.4)	Granular	(220) (200) (111)	A1203 (6.0)	a: 1004			0.52 (Chipping)	0.56 (Chipping)	
	<u></u>	4	Tick(11.3)	Granular	(111) (200) (111)	A1203 (1.9)	K: 404	TiCN- Tim(0.8)	Granular	0.52 (chipping)	0.65 (Chipping)	
	-	a	TiCN(8.1)	Granular	(200) (220) (111)	A12O3 (2.2)	α:100¢	TIN(0.3)	Granular	Failure after 12.8 min. due to Layer Separation	Pallure after 7.5 min. due to Layer Separation	
	~	6	T(CN(4.9)	Granular	Granular (111) (200) (220)	A1203 (S.2)	a: 100%			Pailure after 10.7 min. due to Layer Separation	Fallure after 5.3 min. due to Layer Separation	
Coated Cemented Carbide	۰	U	TiCN(10.3)	Granular	(220) (200) (111)	A1203 (1.1)	\$001°¤	TiM(0.4)	Granular	Failure after 5.6 min. due to Layer Separation	Failure after 0.8 min. due to Fracturing	
Cutting Tools of Prior Art	^	U	T(CN15.5)	Granular	(200) (220) (111)	A1205(1.1)	K: 40F	TIN(0.5)	Granular	Pailure after 10.4 min. due to Layer Separation	Pailure after 3.2 min. due to Practuring	
	•	۵	TICN (6.5)	Granular	(111) (200) (220)	٨١٤٥٥ (٥.6)	a: 1001	TIN(0.3)	Granular	Fallure after 17.1 min. due to Chipping	Failure after 7.9 min. due to Chipping	
	•	•	Tich(3.8)	Granular	(220) (200) (111)	A1203 (8.4)	N: 408			Pailure after 15.4 min. due to Chipping	Failure after 5.2 min. due to Chipping	
	2	۵	TiCN(7.7)	Cranular	(111) (200) (220)	A1203 (2.4)	a: 1001			Pailure after 13.6 min. due to Chipping.	Failure after 7.0 min. due to Chipping	
	=	6	TICN(4.1)	Granuler	(220) (200) (333)	A1203 (0.6)	α:1001			Pailure after 20.8 min. due Chipping (Hilling)	.8 min. due to g)	
	22	is .	Tick(3.9)	Cranular	(111) (200) (220)	A1203 (0.3)	α: 1004	Tin(0.2)	Granular	Pailure after 17.7 min. due to Layer Separation (Milling)	.7 min. due to (Milling)	
	=	L	T(CN(4.4)	Cranular	(220) (200) (111)	A1203 (0.4)	α: 100\$	TIN(0.4)	Granuler	Fallure after 1.0 min. due to Chipping	Fallure after 0.1 min. due to Fracturing	
	7.4	v	TSCN(3.3)	Granular	Granular (111) (200) (220)	A1203 (0.9)	α: 100¢	TIN(0.3)	Granular	Failure after 2.8 min. due to	Failure after 3.2 min. due to	_

TABLE 6

	H				ı	,	Hard Coating Layer					Took Year	
type		Substrate	Innermo	Innermost Layer		Inner Layer	yer	Oute	Outer Layer	Outermo	Outermost Layer	(10)	ŧ.
		<u> </u>	Compo-	Crystal	Coapo-	Crystel	Orientation	Compo-	Crystal	Compo- sition	Crystal Structure	Continuous	Interrupted
	=	4	N. C	Gramler	7 C	Elongated	(1111) (220) (200)	A1203	K: 941	7 in	Gramular	0.13	0.15
	2	<	T.I.R.	Gramiar	ð.	Flongated	(220) (111) (220)	A1203	K: 858			0.15	9.14
	=	<	S P	Gramiler	110	Clongated	(1111) (220) (200)	62.14 Co.	K:100	110	Granular	0.18	0.20
			(R.O.)		2711	5200		(4.1)		(0.8)			
•	91		Tic-	Gramlar	11CN (8.3)	Elongated Growth	(111) (200) (220)	A1203 (2.0)	K: 100%	TIN (0.5)	Granular	9.16	0.21
Coated	2	a	11 S	Gramler	7; C.	Blongated	(111) (220) (111)	A1203	K:731			0.17	0.17
Carbide	2	Ü	4.6 .1.0	Granular	TiCN	Elongated	(220) (111) (200)	A1203	K: 551	T(N (0.3)	Granular	0.17	0.20
Tools of	≂	U	Tic. 6)	Granular	7.CV	Blongated Growth	(220) (200) (111)	A1203	K: 621	71K	Granular	0.20	0.22
	n	۵	Tin (0.6)	Gramler	71CM (6.5)	Elongated Growth	(111) (220) (200)	A1203	K: 734			0.13	0.16
	2	٥	TIN (1.2)	Gramiler	71GR (3.9)	Elongated Growth	(220) (111) (200)	A1203 (8.1)	K: 621			0.16	0.19
	~	a	71CM	Granular	71CV (7.8)	Elongated Growth	(1111 (220) (200)	A1203	K: 1004			0.17	0.18
	52	8	TIN (0.3)	Granular	11CN (4.0)	Elongated Growth	(220) (111) (200)	(9.0)	K: 1001			0.13	(Hilling)
	92	ن	TIN (0.3)	Granular	T1CN (3.5)	Elongated Growth	(111) (220) (111)	A1203	K: 941	T1N (0.0)	Granular	0.15	(Milling)
•	7.2	۵.	Nit (4.0)	Granular	1'1CN (4.5)	Elongated Growth	(220) (111) (200)	A1203	K:1001	T1N (0.4)	Granular	0.15	0.28
	28	u	7118- 7110v	Granular	T.CN (1.C)	Elongated Growth	(311) (320) (111)	A1203 (0.7)	K: 941	T£N (0.2)	Granular	0.14	0.27

TABLE 7 (a)

_			_						, 			·—	
	Flank Wear	(mm)	Interrupted	0.53 (Chipping)	0.50 (Chipping)	0.58 (Chipping)	Pailure after 8.1 min. due to Layer	Failure after 7.5 min. due to Layer	Pallure after 1.7 min. due to Practuring	Failure after 3.7 min. due to Fracturing	Failure after 10.1 min. due to Chipping	Failure after 5.8 min. due to Chipping	
	Flank		Continuous	0.39 (Chipping)	0.43 (Chipping)	0.51 (Chipping)	Pailure after 13.2 min. due to Layer	railure after 14.5 min. due to Layer	Pailure after 8.7 min. due to Layer Separation	Failure after 10.8 min. due to Layer Separation	Peilure after 20.2 min. due to Chipping	Failure after 16.1 min. due to Chipping	Feilure after 14.4 min. due to
		Outermost Layer	Crystal Structure	Cremiter		Granular	Granular		Granular	Granular			
		Outerra	Compo- sition	7 th		45.5 4.5 5.5	1.0)		41k (0.3)	11N (0.5)			
		Outer Layer	Crystal Structure	a: 1001	a:1004	K: 401	a:100%	a:100\$	a:100%	K:408	α:1004	K: 401	a:1004
		Oute	Compo-	A1203	A 29	A1203 (2.1)	A1203 (1.9)	A1203 (4.9)	A1203 (1.1)	A1203 (0.9)	A1203 (5.0)	A1203 (8.2)	A1203 (2.5)
	Hard Coating Layer	Inner Layer	Orientation	(111) (200) (111)	(220) (200) (111)	(111) (200) (220)	(200) (220) (111)	(1111 (200) (220)	(220) (200) (111)	(200) (220) (111)	(111) (200) (220)	(220) (200) (111)	(111) (200) (220)
			Crystal	Granuler	Granular	Granular	Gramlar	Granular	Gramlar	Granuler	Granular	Granular	Granuler
			compo-	71CK	11GN	71CN (11.4)	11CV 18.4)	T.CN (4.2)	TiCN (10.0)	Ticn (5.4)	11CN (6.7)	110 3.8	TiCN (7.6)
		Innermost Layer	Crystal	Gramler	Gramlar	Gramlar	Granular	Granuler	Granuler	Granular	Granular	Granular	Granular
	•	Innerno	Compo-	TIN (3.0)	71N (0.5)	110 (c.0)	TIC- TIN (1.4)	Tin (1.8)	TLN (0.3)	Tic (0.5)	71N (0.4)	71N (1.1)	T1CN (0.5)
		Substrate		<	4	۷	a.	œ	U	U	۵	۵	a
ł				22	2	12	=	57	2	12	2	2	~
		₽ Ø						Coated	Carbide Cutting Tools of Prior Art				

			Ŀ				Hard Coating Layer					Plank Wear	Wear
£		Substrate		Innermost Layer		Inner Layer	ayer	Out.	Outer Layer	Outern	Outermost Layer	(ww)	•
		Togus S	Compo-	Crystal	Compo-	Crystal Structure	Orientation	compo- sition	Crystal Compo- Crystal Structure Sition Structure	Compo- sition	_	Continuous Interrupted Cutting	Interrupted Cutting
	25	E 1	TIN (0.3)		71CV (3.9)	Granular	(220) (200) (111)	(9.0)	a:1001			Failure after 26.7 min. due to Chipping (Milling)	r 26.7 min. ing
Coated	56	ů	TiN (0.3)	Granular	71CN (3.4)	Gramlar	(111) (200) (220)	A1203 (0.4)	a:100%	Tin (0.3)	Granular	Pailure after 23.3 min. due to Layer Separation (Milling)	r 23.3 min. Separation
Carbide Cutting Tools of Prior Act	23	ů.	TIN (0.6)	Granular	71CV (4.4)	Granular	(220) (200) (111)	A1203	a:100%	TIN (0.4)	Granular	Pailure after 1.2 min. due to Chipping	sfler 1.2 after 0.1 min. due to chipping Fracturing
	78	U	TICN TICN	Granular	110 (5.2)	Gramlar	(111) (200) (220)	A1203 (0.8)	a:1001	TiN (0.3)	Granular Pailure after 3. min. due	Pailure after 3.0 min. due to	after 3.0 after 0.2 min. due to

TABLE 7 (b)

TABLE 8

				,		,	_ 4	0								
Mear	2	Inter- rupted	61.0	0.18	0.29	0.28	0.20	97.0	0.25	0.20	6.27	0.24	(K11) (mg)	(Miling)	0.26	0.24
Plank Weer	(mm)	Conti- nuous	0.15	0.18	0.18	0.15	0.19	0.19	0.25	0.15	0.16	0.16	0.15	0.14	0.16	0.14
	Outermost Layer	Crystal Structure	Gramlar		Granular	Granular		Granular	Granular					Granular	Granular	Granular
	Outermo	Compo- sition	TEN (0.2)		Ticn- Tin	Tiv (0.2)		Tin (0.3)	TIN (0.3)					TiN (0.2)	TSN (0.2)	TiN (0.3)
	Outer Layer	Crystal Struc-	K: 941	K: 854	K:1008	X:1004	K:736	K: 551	K: 621	K:734	K:621	K: 1001	K: 1001	K:941	K: 1004	K: 941
	Outer	COMPO- SICION	A1203	A1203	A1203 (2.1)	(1.7)	A1203	A1205	A1203	A1203	A1203	A1203	A1203	A1203	A1203	A1203 (0.6)
	First Intermediate Layer	Crystal Struc-	Gramlar	Gramlar	Granular	Gramiar	Granular	Granular	Granular	Grenular	Granular	Granular	Granular	Granular	Granular	Granular
Ing Layer	First Intermedi Layer	Compo-	11C	71C (2.4)	11C (2.3)	11c (3.9)	11c	7.tc (3.2)	11N (1.9)	71C (2.8)	11Ck	T1C (2.3)	75C (1.5)	71C (1.6)	T(CN (1.3)	Tic (1.0)
Hard Coating Layer	yer	Orientation	(111) (220) (200)	(220) (111) (200)	(111) (220) (200)	(111) (200) (220)	(111) (220) (200)	(220) (111) (200)	(220) (200) (111)	(111) (220) (200)	(220) (111) (200)	(111) (220) (200)	(220) (111) (200)	(111) (220) (200)	(220) (111) (200)	(111) (220) (200)
	Inner Layer	Crystal Structure	Elongated	Elongated Growth	2	Elongated Growth	Elongated Growth	Blongated Growth	Elongated Growth	Elongated Growth	Elongated Growth	Elongated Growth	Elongeted Growth	Elongated Growth	Elongated	Elongated Growth
		Compo- sition	71CN	5 G	11CV	TiCN (4.5)	71Ck	71CN (6.8)	71CV (3.3)	TiCN (3.6)	TiCN (2.6)	TiCN (5.6)	TICN (2.5)	T-1CN (2.7)	TICN (3.5)	71CN
	nnermost -Layer	Crystal Struc-	Gramlar	Gramlar		Gramlar	Gramlar	Gramler	Gramlar	Granular		Granular	Granular			Granular
	Innermo	Compo- sition	11.00 10.00	11N (0.5)		Tic-	15N	TIN (0.1)	15C (0.7)	15N (0.6)		4.6 (0.4)	71N (0.3)			TIN- TICN
į.	strate Symbol		<	<	<	a	•	v	U	Δ	٥	۵	tes	.2	6	U
			23	ñ	ä	32	2	ř	25	2	7	z	۾	2	=	ç
	ž.						Coated	Carbide	Tools of the	Invention			-			

TABLE 9 (a)

Wear	a)	Interrupted Cutting	0.54 (Chipping)	0.53 (Chipping)	0.48 (Chipping)	Pailure after B.8 min. due to Layer Separation	Failure after 6.2 min. due to Layer Separation	Failure after 1.4 min. due to Fracturing	Pailure after 4.1 min. due to Precturing		railure after 6.4 min. due to Chipping	Pailure after 8.2 min. due to
Flank Wear	(mar)	Continuous Cutting	0.43 (Chipping)	0.50 (Chipping)	0.50 (Chipping)	Pailure after 13.9 min. due to Layer Seperation	Failure after 11.1 min. due to Leyer Separation	Failure after 6.8 min. due to Layer Separation	Pailure after 11.6 min. due to Layer Separation	Failure after 18.5 min. due to chipping	Failure after 16.8 min. due to Chipping	rellure after 14.7 min. due to
-	Outermost Layer	Crystal Struc- ture	Granular		Oranular	Granular		Granular	Granular			
	Outern	Se	71N (0.2)		Tich- Tin (0.6)	TİN (0.2)		TIN (0.3)	75N (0.4)			
	Outer Layer	Crystal Struc-	a, 100%	a: 1004	K: 404	a:1001	α: 100 1	a: 1001	K: 408	æ:100#	K: 401	a: 1001
	Outer	compo- sition	A)203	A3203	A1203 (2.1)	A1203 (1.8)	A1203 (3.9)	A1203	A1203 (1.0)	A1203 (4.8)	A1203 (8.1)	A1203 (2.7)
4	First Intermediate Laver	Crystal Struc-	Gramlar	Granular	Gramular	Granuler	Granular	Granular	Granular	Granular	Granular	Granular
ng taye	Intern	100	7.ic (2.5)	2.1°	Tic (2.1)	0.4 0.9	71c (1.2)	71c (2.5)	71N (1.8)	71C (2.9)	TiCN (1.1)	71C (2.5)
Hard Coating Layer	ayer	Orientation	(111) (200) (220)	(220) (200) (111)	(111) (200) (220)	GEANULAE (200) (220) (111)	Granuler (111) (200) (220)	(220) (200) (111)	Granular (200) (220) (111)	Granular (111) (200) (220)	Granular (220) (200) (111)	Granular (111) (200) (220)
	Inner Layer	Crystal Struc-	Gramler	Granular	Granular	Granular	Granular	Granular	Granular	Granular	Granular	Granular
		9 19	7 F S	17 C	7.65 18.51	71CN (4.7)	4.0)	11.CN (S.B)	1.0 (5.2)	T)CN (3.5)	T1CN (2.7)	TiCN (5.7)
:	Innermost Layer	Crystal Struc-	Gramular	Gramler		Gramlar	Granular	Granular	Granuler	Granular		Granular
	Innermo	Compo-	TIN	Nit S. 0		TiC- TiN (1.2)	11N (1.1)	15k (0.1)	T.S. (0.6)	410 (0.4)		TiCN (0.5)
į	strate	•	~	~	4	æ	•	U	U	۵	٥	۵
			8	Š	Ä	ñ	2	7	32	<u> </u>	5	2
	ę,						Coared	Carbide Cutting Tools of Prior Art				

Flank Wear	(mm)	Interrupted Cutting	er 19.7 min. Jing	Fallure after 19.3 min. due to Layer Separation (Milling)	Failure Pailure after 1.4 after 0.1 min. due to min. due to Chipping Precturing	Pailure Failure after 3.2 after 0.3 after for min. due to min. due to min. due to Practuring
Flank	E)	Continuous Interrupted Cutting	Pailure after 19.7 min. due to Chipping (Milling)	Granular Pailure after 19.3 min. due co Layer Separation (Milling)	Granular Pailure Pailure after 1.4 after 0.1 nafn. due to min. due Chipping Practurin	Pailure after 3.2 min. due to Chinning
	Outermost Layer	Crystal Struc- ture		Granular	Granular	Tin Granular Pailure (0.2) after 3. min. due
	Outerm	Compo- sition		T1N (0.3)	TIN (0.3)	
	Outer Layer	Compo- Crystal sition Struc- ture	a:100£	a:1001	a:100)	a: 1001
	Outer	Compo- Crystal sition Struc- ture	81203 (0.5)	A1203	A1203 (0.3)	A1203 (0.7)
1	First Intermediate Laver	Crystal Struc- ture	Granular	TiC Granular Al203	Granular	TiC Granular Al203
53 53	Inter	Compe	71c (1.4)		11CN (1.4)	71C (1.1)
Hard Coating Layer	Layer	Orientation	Granular TiCN Granular (220) (200) (111)	TiCN Granular (111) (200) (220)	TiCN Granular (220) (200) (1111 TiCN Granular (1.4)	Ticn Granular (111) (200) (220) (1.9)
	Inner Layer	Crystal Struc-	Granular	Granular	Granular	Granular
		Compo-	71CN (2.5)	TiCN (2.6)	71CN 03.40	
	Innermost Layer	Compo- Crystal sition Struc-				Gramlar
	Innerm	Compo- sition	TÎN (0.3)			71N- 71CV (0.9)
4	strate Symbol		w	i.		o
			ñ	Ç	ş	ទ
	£ .	•		Control	Cutting Tools of Prior Art	

TABLE 9 (b)

TABLE 10

	Г					Hard Co	Hard Coating Layer					Plank Wear	Wear
ş		Substrate		Inner Layer	iyer	18	Second	Oute	Outer Layer	Outere	Outermost Layer	(uu)	2
		Symbol				Intermed	Intermediate Layer						
			-odwoo	Crystal	Orientation	Compo	Crystal	Compo-	Crystal	Compo	Crystal	Continuous Interrupted	Interrupted
		,	sition	Structure		sition	Structure	sition	Structure	11100	Structure	Cutting	CULTING
	6	4	ē	Blongated	(111) (220) (200)	1,000	Granular	A1203	K: 940	ž	Granular	0.15	0.17
_			(8.4)	Growth		(0.1)		(2.0)		(0.5)			
	3	۷	110	Elongaced	(220) (111) (200)	TICNO	Granular	A1203	K: 851			0.16	0.17
			(5.7)	Growth		(0.1)		(0.9)					
	Ş	4	11CM	Elongaced	(111) (220) (200)	71000	Oranular	A1203	K:1001	57	Granular	0.15	0.19
			9:10	Growth		69.13		6.13		¥ 5			
	٤	•	ğ	Elongated	Elongaced (111) (200) (220)	1100	Granular	13.03	K.100h	T.	Granular	0.14	0.30
			(8.2)	Growth		(0.1)		2.1		(0.3)			
Coated	÷	a	11CN	Blongated	(111) (220) (200)	1100	Granular	10ZTY	K:738			0.17	0.19
200	;	,	Ž	P) contract and	199011111110001	3	Seamille.	10:51	1	Z	Gramilar	0.18	0.21
Cutting	;	,	(30.2)	Groveh		9.7		17.7		(0.3)			
Tools of	÷	U	43.5	Blongsted	(220) (200) (111)	1100	Granuler	A1203	K: 621	TIN	Gramaler	0.22	0.23
che			(5.4)	Growth		(0.1)		(0.9)		(0.4)			
Invention	95	Ω	T1CN (6.5)	Elongated Growth	(111) (220) (200)	71CNO	Gramler	A1203	K:941	TIN (0.2)	Gramular	0.13	0.18
	ន	۵	410	Blongated	(220) (111) (200)	41000	Gramlar	A1203	K: 621			0.12	0.21
			(3.8)	Growth		(0.1)		(8.2)					
	25	a	7.02	Blongated	(111) (220) (200)	T1CH0	Gramler	A1203	K:100#			0.14	0.19
			(7.7)	Growth		(0.1)		(2.4)			,		
	S		TICN	Elongated	(220) (111) (200)	TICNO	Granular	A1203	K:1004			0.14	(Hilling)
			(4.1)	Growth		(0.1)		(0.6)			Ţ		
	\$.2	410	Elongated	Elongated (111) (220) (200)	T.C.NO	Granular	A1203	876:X	TIN	Gremuler	0.16 ((Milling)
			14.0)	Growth		(0.1)		(0.5)		(0.3)			
•	\$\$		4.4.	Elongated Growth	(220) (111) (200)	7100	Granular	A1203	K:1004	41N (0.3)	Granular	0.12	0.18
	98	0	Tick	Elongated	Elongated (1111) (220) (200)	TICHO	Gramlar	A1203	K: 941	N.T.	Gramilar	0.13	0.17

TABLE 11 (a)

	Г					Hard Co	Hard Coating Layer					Plank Wear	Mear
م		Substrate		Inner Layer) Ac	Intermed	Second Intermediate Layer	Outen	Outer Layer	Outern	Outermost Layer	(44)	_
			Compo-	Crystal	Orientation	Compo-	Crystal Structure	Compo- strion	Crystel Structure	Compo- sition	Crystal Structure	Contimous	Interrupted
	2	4	Ð 5	Granular	(111) (200) (220)	71CN0	Gramler	A1203	a:1008	TIN (0.4)	Granuler	O.42 (Chipping)	0.54 (Chipping)
	3	4	<u>5</u>	Gremler	(220) (200) (311)	71CN0	Gramier	1,20,1	a:1001			0.47 (Chipping)	0.51 (Chipping)
	÷	<	710r (11.5)	Granular	(1111) (200) (220)	TiCHO (0.1)	Gramler	A1203	K: 408	11CH 11H (0.7)	Grenuler	0.43 (Chipping)	0.55 (Chipping)
	\$		710 (6.3)	Granular	(200) (220) (111)	TiCM0 (0.1)	Gramler	A1203 (2.0)	a:1001	718 (0.0)	Grænulær	Pailure after 17.5 min. due to Leyer Separation	Pailure after 11.1 ain. due to Layer Separation
Coated	÷	a	71.CK	Granuler	(111) (200) (220)	6.2. (5.2)	Granular	A1203 (5.2)	G :100			Pallure after 14.0 min. due to Layer Separation	Failure after 7.8 min. due to Layer Separation
Carbide Cutting Tools of Prior Art	=	U	TiCN (10.3)	Granular	(220) (200) (111)	60.11 10.11	Granular	A1203 (1.3)	a:1001	TIN (0.2)	Granular	Pailure after 8.2 min. due to Layer Separation	Failure after 1.2 min. due to Fracturing
	9	U	11CH (5.2)	Granular	(200) (220) (111)	71,CMC (0.1)	Granular	A1203 (0.9)	K: 408	T5N (0.5)	Granular	Failure after 13.6 min. due to Layer Separation	Fellure ofter 5.3 min. due to Fracturing
•	8	a	7.5 6.6	Granular	(111) (200) (220)	71CNO (0.1)	Granuler	A1203 (5.5)	a, 100%	TIN (0.3)	Granular	Fallure after 20.7 min. due to Chipping	
	ž	٥	71CN (5.2)	Granular	(220) (300)	T1CN0 (0.1)	Granuler	A1203 (8.1)	K1 401			Failure after 18.9 min. due to Chipping	
	\$	۵	71CV (7.8)	Granular	Granular (111) (200) (220)	T1CN0 (0.1)	Grenuler	A1203 (2.3)	a:1004			Pailure after 16.3 min. due to	Failure after 10.1 min. due to

5

	Г					Herd C	Mard Coating Layer					Plank Wear	X NO.
type		Substrate		Inner Layer	syer	Se Trace	Second forermediace Laver	Otte	Outer Layer	Outerm	Outermost Layer	(mm)	7
•			Compo-	Compo- Crystal	Orientation	Compo-	Compo- Crystal Compo- Crystal	Compo-	Crystal Compo- Structure sition	Compo- sition	Crystal Structure	Crystal Continuous Interrupted Structure Cutting Cutting	Interrupted
	3	Es .	7.CN (4.2)	Granular	Granular (220) (200) (111)		Granuler	120	a: 100%	·	·	Pailure after 26.9 min. due to Chipping (Milling)	r 26.9 min. Ing
Coated	3	ė	11CN (4.0)	Granular	(111) (200) (220)	TLCNO (0.1)	Gramler	A1203 (0.4)	a: 1001	TiN (0.2)	Granular	Granular Pailure after 24.2 mln. due to Layer Separation (Milling)	r 24.2 mln. Separation
	8		71CN (4.5)	Granular	(220) (200) (111)	7100 (0.1)	Granular	A1203 (0.3)	a:1001	TÎN (0.4)	Granular failure after 2.0 min. due Chipping	failure failure after 0.2 after 0.2 ain. due to min. due to Chipping Frecturing	Failure after 0.2 min. due to Frecturing
	*	o	TiCk (3.2)	Granuler	Granuler (111) (200) (220) †1CNO (0.2)	71CNO (0.2)	Granular	A1203 (0.8)	a:1001	TIN (0.2)	Granular Pailure after 5. min. due	Pailure after 5.2 min. due to	efter 5.2 after 0.7 min. due to min. due to

TABLE 11 (b)

TABLE 12

			_										_				
Flank Weer	2	Inter- rupted	Cutting	0.14	0.13	0.15	0.16	0.17	0.19	0.21	0.15	0.17	0.15	(Milling)	(M1111mg)	0.16	0.15
Flank	(122)	Conti-	Cutting	0.13	0.15	0.14	0.13	0.16	0.17	0.20	0.12	0.11	0.13	0.12	0.14	0.11	0.11
	Outermost Layer	Crystal Structure		Gramular		Granuler	Granular		Granular	Granuler	Granuler				Granular	Granular	Granular
	Outerm	CORDO- SILION		71H (0.5)		TICH- TIN (0,7)	11N (0.3)		N74 (0.0)	71/H (0.5)	7£N (0.2)		,		71N (0.3)	T1N 10.51	T1N (0.2)
	Outer Leyer	Crystal Struc-	ture	K: 941	K: 858	K: 1001	K:1001	K:738	K: 554	K:628	K:948	K: 62%	¥:1004	1001:x	K:941	K:100#	K:941
	Outer	Compo- sition		A1203	A1203	A1203 (1.8)	A1203 (2.0)	(5.1)	(1'1)	A1203	A1203	A3203	A1203	19.61	A3.203	(6.3)	10.81
	Second Intermediate Layer	Crystal Struc-	ture	Granular	Granular	Granular	Granular	Granuler	Granular	Granular	Granuler	Granuler	Granular	Granular	Granular	Granular	Granular
ing Leyer	Intern	Compo- sition		1,00	71CM (0.1)	11CHO (0.1)	71G80 (0.1)	7100 (0.2)	#(0.1)	T1CN0 (0.1)	T1CN0 (0.1)	T1CN0 (0.1)	T(C)()	TiCNO (0.1)	Ticno (0.1)	7iC0 (0.1)	TiCNO (0.2)
Hard Coating Layer	Jaga	Orientation		(111) (220) (200)	(220) (111) (200)	(320) (320)	(323) (200) (330)	(111) (220) (111)	(220) (111) (200)	(220) (200) (111)	(111) (220) (200)	(220) (111) (200)	(111) (220) (111)	(220) (111) (200)	(111) (220) (111)	(220) (111) (220)	(111) (220) (200)
	Irner Layer	Crystal Structure		Blongated Growth	Elongated Growth	Blongated Growth	Elongated Growth	Elongated Growth	Elongated Growth	Blongated Growth	Elongated Growth	Elongated Growth .	Elongated	Elongated Growth	Elongated	Elongated	Elongated
		Compo- sition		TiCN (8.5)	T1CN (5.6)	TICN (11.5)	11CM (8.2)	TICN (4.9)	TICN (10.1)	Tick (5.3)	Tick (6.4)	71CN (3.6)	TiON (7.8)	T1CN	TÍCN (4.1)	T1CN (4.6)	71Ck (3.1)
	Innermost Layer	Crystal Struc	ture	Gramlar	Granular	Gramler	Granular	Gramlar	Gramlar	Gramlar	Granular	Gramler	Gramlar	Cramiar	Granutar	Granuler	Granular
	Innerno	Compo- sition		# (0.1)	118 (0.5)	11Cs (0.8)	11C- 15N	71N (1.6)	TIN (0.1)	7£C (0.5)	T1M (0.6)	TSN (1.2)	7.CN	TÎN (0.3)	T1N (0.3)	TIN (0.7)	1114- 1108
-qng	strate Symbol			∢	~	4	<u>a</u>	a	3	U	۵	۵	۵	B	ė		9
		-	٦	53	g.	53	9	13	29	63	3	89	99	67	89	69	70
	ę.							Coated	Carbide	Tools of the	Invention						

TABLE 13 (a)

	4	<u> </u>				Hard Coating Layer	ng Layer						Flank Wear	#ear
170	Strate		Imermost Layer		Inner Layer	ayer	å	Second	Outer	Outer Layer	Outern	Outermost Layer		e
	Symbol						Intera	Intermediate						
			Crystal	Compo	Crystal	Orientation	-	Crystel	Compo-	Cryste		Crystal	Continuous	Interrupted
	_	9		sition	Struc-		e it is	Struc-	sicion	-	attion	Struc-	Cutting	Cucting
			ture		ture			ture		Struc- ture		ture		
	52	A Tin	Granular	₹ 100°	Granular	(111) (200) (220)	Ticko	Granular	A1203	a: 1001	TIN	Gramlar	0.38	15.0
		_	_	6.6			(0.1)		(2,1)		(0.5)		(chipping)	(Chipping)
	28	AIL	Granular	L	Granular	(220) (200) (111)	H	Granular	A1203	G: 1001			0.41	0.49
	_	(0.6)	10	(5.3)			(0.1)		(\$.2)				(Chipping)	(Chipping)
	65	A TICH	N Granular	110v	Gramlar	(111) (200) (220)	T1CN0	Granular	A1203	K: 401	Tich-	Gramlar	0.40 (Chipping)	0.54 (Chipping)
	_		-								(0.6)			
	09	B Tic.	- Gramlar	L	Granular	Granular (200) (220) (111)	-	Granular	A1203	a: 100%	TIN	Gramlar	Pailure	Failure
		TIN		(8.1)			17.0		(2.2)	-	(6.5)		after 16.8	after 12.3
	_	-											faver	Laver
										٠			Separation	Separation
	179	B Tin	Gramlar	L	Granular	(111) (200) (220)	-	Granular	A1203	g: 1004			Pailure	Pailure
		13.61		€. 8			(0.3)		(8.0)				efter 15.1	after 8.6
Coated													min. due to	min. due to
Cemented								•					Layer	Layer
Carbide	┙	1	+	4			+		Ī				Separation	Separation
Cutcing	79	TIN	Granular	TICK	Granular	(220) (200) (111)	35	Granular	A1203	a: 1004	Z	Granular	Pailure	Pailure
Tools of	_			(10.2)					(8.0)		<u> </u>		After 9.0	ofter 1.7
Prior Art													min. due to	Ain. due to
•••													Separation	Burranger
	2	C 71C	Cramlar	Ticn	Granular	Granular (200) (220) (111)	TICNO	Granular	A1203	X:408	412	Gramiler	Pailure	Failure
		6.0	=	(5.4)			9.1		(1.0)		(9.6)		after 14.6	after 5.9
	-		_										min. due to	min. due to
			_										Layer	Fracturing
		1	1	4	10000	102271000711111	Ca Cy de	200000	10014				Patitive	Fe (1 u.c.
			_	3 9	101010	(2011)	_			4:100			ofter 21.4	Afrer 12.3
		-							(5.5)				min. due to	min. due to
													Chipping	Chipping
•	55	D TIN	N Granular	L	Granular	(220) (200) (111)	TYCNO	Granular	A1203	X:408			Pailure	Failure
		11.31		(3.8)			(0.3)		(8.2)				after 19.5	after 9.3
													min. due to	min. due to
	_			_			-						Chipping	Chipping
	99	TiCN	N Granular	Š	Granular	Granular (111) (200) (220)	_	Granular	A1203	a: 1001			Pailure	Failure
		<u>.</u>	<u>-</u>	17.7			6.1		(2.3)				after 17.1	after 10.8
		_							_				min. due to	min. due to

TABLE 13 (b)

		Šě					Hard Coating Layer	ng Laye						Flank Wear	Weas
P. C.		strate Symbol	Innerm	Innermost Layer		Inner Layer	Ayer	Interi	Second Intermediate Layer	Outer Layer		Outerno	Outermost Layer	(mm)	(u
			Compo- sition	Crystal Struc- ture	Compo- sition	Crystal Struc- ture	Orientation	Compo- sition	Crystal Struc- ture	Compo- sicion	Crysta 1 Struc- ture	Compo- altion	Crystal Struc- ture	Core ing Core ing	Interrupted Cutting
·	69	ш	TiN (0.3)	Granular	11CN	Granular	Granular (220) (200) (111)	T1CNO (0.1)	Ticho Granular (0.1)	A1203 (0.6)	\$001 to			Failure efter 28.0 min. due to Chipping (Milling)	r 28.0 min. Ing
Coated Cemented Carbide	89		TIN (0.3)	Granular	13.9)	Granular	Granular (111) (200) (220)	T1CNO (0.1)	TiCNO Gramiar (0.1)	A1203 (0.4)	4001 :D	TÎN (0.3)	Gramlar	Gramlar Pailure after 24.8 min. due to Layer Separation (Milling)	r 24.8 min. Separation
Cutting Tools of Prior Art	69	b.	11.01 (0.7)	Granular	710k	Granular	Granular (220) (200) (111)	1100 (0.1)	Granular	A1203 (0.4)	a: 100%	TÅN (0,4)	Oramlar Pailure after 3 min. du	.s to	Failure after 0.2 min. due to Practuring
	20	U	75N- 75CN (1.0)	Gramlar	110 (3.3)	Granular	(1111) (200) (220)	T1CNO (0.2)	Granular	A1203 (0.9)	a: 1001	T£N (0.2)	Gramlar Pailure after 5. min. due	Pollure Failure after 0.9 min. due to min. due to	Failure after 0.9 min. due to

5

TABLE 14

		-qns					Hard Coating Layer	ing Layer						Flank Wear	Wear
\$	- 4	strate Symbol		Inner Layer	ayer	Inter	First Intermediate Laver	Sec	Second Intermediate	Outer	Outer Layer	Outers	Dutermost Layer		•
			Compo	Crystal	Orientation	-Sego	Crystal	-ocus	Crystal	- OGEO C	Coyatal	Compo-	Crystel	Cont.1-	Inter-
			sition	Struc-			Struc-	sition	Struc-		Struc- ture	sitia	Structure	Cutting	Cutting
	F	{	10.1	Elonosted	(111) (220) (200)	ž	Gramular	1,000	Gramular	10,01	27.0.72	ž	Gramlar	0.16	0.20
			(6.3)	Growth		(3.2)		(0.1)		(2.3)		(0.2)			
	72	<	11CM	Elongated	(220) (111) (220)	274 41C	Granular	TICNO	Gramler	A1203	K:851			67.0	0.19
			(1.1)	Growth		(2.0)		(0.1)		10.91					
	13	٧	T1CN [9.4)	Elongated Growth	(111) (220) (200)	†1c (2.0)	Granular	TiCN0 (0.1)	Grenuler	A1203 (2.1)	K: 1004	Tics- Tin (0.7)	Gramlar	0.16	0.21
	7	•	7.1CN (4.6)	Elongated Growth	(111) (200) (220)	11c	Granular	T(CN)	Oramilar	A1203	K:1004	TEN (0.3)	Gramlar	0.15	0.23
Control	2.	•	71CN (4.8)	Elongated Growth	(111) (220) (200)	11°C	Gramlar	#100 (0.1)	Gramular	A1203	K:734			0.19	0.21
Carbide	9.	ű	7.ICN (6.6)	Elongated Growth	(220) (111) (200)	110 (3.1)	Granular	1100 (0.2)	Granular	A1203	K: 551	TÎN (0.3)	Granular	0.20	0.24
Tools of the	۲۲	٥	7.CX (3.3)	Elongated Growth	(220) (200) (111)	TiN (1.9)	Gramlar	T1CN0 (0.1)	Gramlar	A1203	K1628	TÍN (0.5)	Gramilar	0.25	0.25
Invention	8.6	٥	T1CN (3.5)	Elongated Growth	(111) (220) (111)	11C (2.9)	Granular	Ticko · (0.1)	Granular	A1203	\$6413	TIN (0.5)	Granular	0.15	0.19
	6.	q	TLCN (2.4)	Elongated Growth	(220) (111) (220)	TLCN (0.6)	Grenuler	T1CN0 (0.1)	Granular	A1203	K: 621			0.14	0.22
	08	٥	TICN (5.5)	Elongated Growth	(111) (220) (111)	T1C (2.6)	Grenular	T1CNO (0.1)	Oranular	A1203	K: 1001			0.15	0.21
	19	1	T1CN (2.6)	Elongated Growth	(502) (111) (522)	71c (1.3)	Granular	T1CNO (0.1)	Granular	A1203	K: 1004			0.15 (1	(Milling)
	62	. 19	T1CN (2.3)	Blongated Growth	(311) (320) (300)	71C (1.5)	Granular	Ticho (0.1)	Granular	A1203	K:941	TIN (0.2)	Granuler	ו) רנ.0	(Hilling)
	63		TiCN (3.4)	Elongated Growth	(320) (111) (322)	Tick (1.2)	Granular	11.0)	Granular	A1203	K: 1001	TIN (0.3)	Granuler	0.14	0.20
_	94	v	11CN	Slongated	(111) (220) (111)	110	Granular	TICNO	Granular	A1203	K: 948	TIN	Granular	6.13	0.19

TABLE 15 (a)

_				_	_	_			_	_	_	-		-	_	_	_	_	_	_	_							-	_	_	_	_	-				_	
	Wear	ta a	Interrupted Cutting		0.53 (Chiming)	0.52	(Chipping)	0.40	· Currier of	Pailure	after 9.5	min. due to	Separation	Patlure	after 6.3	min. due to	Layer	Separation	Pailure	ofter 1.2	min. due to	Practuring		Pallure	BICCE 4.4	Min. due co	Fracturing	Failure	after 9.5	min. due to	Chipping	Pailure	after 6.8	min. due to	Chipping	Failure	after 8.4	min. gue to
	Plank wear	(mm)	Continuous Cutting		0.43 (Chirolpo)	\$ 0	(Chipping)	0.37	Carried and	Pailure	after 14.7	Ein. due to	Separation	Patlura	After 12.1	min. due to	Layer	Separation	Failure	after 6.8	ain. due to	Layer	Separation	Fallure	ercer 11.9	MIN. GUE LO	Separation	Failure	After 18.6	min. due to	Chipping	Failure	after 17.0	min. due to	Chipping		After 15.9	min. due to min. due to
		Outermost Layer	Crystal Struc-	ture	Gramler			Crampar		Grenular			•						Gramler					Gramiar				Granular					•				_	
		Outern	Compe- eleton		T.IN			TION-	(0.6)	Z.F.	(0.3)								TÉN	€.				2	3 .			Z.	6.5									
		Layer	Cryste 1	Struc- ture	a: 1001		1007:5	K: 404		4:300%					1001:3				a: 100%					K:404				4.1004				K: 404				a: 1001		
		Outer Layer	compo- sicion		A1203		3 6 6	A1203	2.2	A1203	(1.9)			5014	5	- -			A1203	17.11				A1203	60.83			A170,				A1203	(8.1)	i !		A1203	(5.6)	
		Second Intermediate Laver	Crystal Struc-	ture	Gramiler	2001		Gramiar		Cranular				rem.ler	1917017				Gramular					Granular				Grenuler				Grenuler				Granular		
	g Layer	15ter 2	11.00	_	T1CN0	+	_	Ticko	3.00	TICNO	6.3			8,5	3 3				418	(0.3)			_	_	?: !				(0.1)		-	TICNO	9.5			TICNO	: : :	_
	Hard Costing Layer	Pirst Incermediate Laver	Crystal Struc-	ture	Granular		_	Gramlar		Granular				100	1				Gramular				-	Gremiler				Granular				Gramular				Granular		
	•	Incer	1		ν. (, e	110	17.7	27.5	5.3			Ş	1 2				27.5	6.3				Z i	3 :5			Tic	(2.8)			41.0v	3.3			710	(2.S)	
		ayer	Orientation		(111) (200) (220)	111111000110001	11111 (007) (077)	(111) (200) (111)		Granular (200) (220) (111)				1025, 1006, 1111,	10771 (007) (777)				Gramiar (220) (200) (111)					Gramiar (200) (220) (111)				(111) (200) (220)				(111) (200) (111)				(111) (200) (220)		
		Inner Layer	Crystal Struc-	ture	Gramilar	_		Gramiar		Granular					1 TO				Gramler					Gremiter				Gramlar				Gramlar				Gramiar	_	_
			Compo- strion		Tick	1	56.5	P.I.CM	7.5	7 <u>1</u> 5	5.3			24.6	2 2				Š	(6.7)				č	0.2			Š	3.			Ti Cv	÷.			TICN	3.5	
	-ig	strate Symbol			~	1	<	~	_						•				J	_				u								٥				a		
	Г				2	1	-	E		F				1	?				2				٦	٤	_			=				6				80		
		Ę.	•						_				_			Coated	Cemented	Carbide	Otting	Tools of	Prior Art		•															

		-ans				-	Hard Coating Layer	39 Laye						Plank Weer	Wear
Ay Ct		Symbol		Inner Layer	bye.	Interi	First Intermediate Laver	Interi	Second Intermediate Laver	Outer	Layer	Outern	Outer Layer Outermost Layer	96)	2
			Compo- sition	Crystal Struc- ture	Orientation	of the	Crystal Struc- ture	Compo- eltion	stal uc-	Compo- Crysta sition 1 Struc-	Crysta 1 Struc: ture	12.00	Crystal Struc- ture	Continuous Interrupted Cutting	Interrupted
	8	ш	71CV (2.4)	Granular	Granular (220)(200)(111)	7fc (1.5)	Granular TiCNO Granular (0.1)	71CM (0.1)	Granuler	A1203 (0.4)	a: 1004			Pailure after 23.2 min. due to Chipping (Milling)	r 23.2 min. Ing
Cemented	2	ù	71CN (2.5)	Granuler	Granular (111)(200)(220) TiC Granular FiCNO Granular (0.1)	11.0 11.0	Granular	T(CN0 (0.1)	Granular	A1203	a:1001	TIN (0.2)	Granuler	Granular Pallure after 20.1 min. due to Layer Separation (Hilling)	r 20.1 min. Separation
Cutting Tools of Prior Art	2		11CH (3.3)	Gramiar	Gramlar (220)(200)(111) TICN	1104	Granular	(0.1)	Granular TiCO Gramiar A1203 (0.1)		a:1001	758 (0.2)	Granular Failure After 1 After 1 After 1 Chipping	9. e to	Failure after 0.1 min. due to Frecturing
	ž	v	T(CN (1.8)	Granuler	Granuler (111)(200)(220)	7ic (1.0)	Granular	71CM (0.2)	Granular TiCNO Granular (0.2)	A1203	a: 1001	11x (0.3)	Grenular Peilure after 3	2 S	Failure after 0.3 min. due to

TABLE 15 (b)

TABLE 16

		¥				_				_	_	٥	â	6		T
Flank Weer	(EE)	Interrupted Cutting	67.6	9.18	0.20	0.22	0.19	0.23	0.24	0.19	0.31	0.20	(Hilling)	(Milling)	0.19	0.38
71.6		Conclauous Cacting	0.15	0.17	0.15	0.14	0.18	91.0	0.23	0.13	0.13	0.14	0.14	0.16	Ct.0	0.13
	Outermost Layer	Crystal Struc- ture	Oremiler		Gennlar	Oreaniler		Oremeler	Oceanitae					Or arrula r	Or emule r	
	8 3	Carre	71H (0.2)		12.0 10.6	1.0 (2.0)		0 .3 E	7112 (0.5)					TÍN (0.2)	(C.0)	TLN
	Outer Layer	Crystal Struc- Crystal	496°M	K: 851	K: 1004	K:1001	K:738	x:554	K:621	K:734	K:621	¥:1004	K: 1001	K:941	10011X	K1941
	Oute	a file	A1203	A1203	A1203	13.93	A3203 (3.9)	A1203	A3203	A2203	A3203	A3203 (2.8)	A1203	A1203 (0.3)	A1203	A1203
	Second Intermediate Layer	Crystal Struc- ture	Orentlas	Grunulas	Granular	Oremiles	Oremilar	Granular	Cramiler	Granular	Gramber	Grenular	Grenular	Granular	Gramules	
u	Inter	Campa	71CHO (0.1)	71CNO (0.1)	Ticko (0.1)	T1CNO 10.1)	TiC0 (0.1)	T1C0 (0.2)	TICNO 10.11	TICNO (0.1)	Ticko (0.1)	Ticho (0.1)	T1CNO (0.1)	T1CNO (0.1)	71C0	TICNO
Hard Coating Layer	First Intermediate Layer	Crystal Struc- ture	Granular	Granular	Gramulas	Oranulaz	Gramular	Gramlar	Or emuler	Gramilar	Gremlet	Grambar	Granular	Granular	Granuler	
ard Coal	Intera	attien.	T(C)	TIC (2.3)	(1.5)	11c (3.8)	TIC (1.2)	T1C (3.0)	11.71	T1C (2.8)	11.04	71C (2.5)	71C (1.4)	T1C (1.5)	Tio	7,7
x		Ordentation	(111) (226) (111)	(230) (1111) (260)	(111) (230) (100)	(111) (260) (111)	(111) (220) (200)	(330) (111) (300)	(111) (300) (111)	(111) (220) (100)	(320) (111) (360)	(111) (220) (200)	(230) (111) (200)	(111) (120) (180)	(220) (331) (200)	
	Inner Layer	Crystal Structure	Elemented Growth	Elonga cad Oranch	Elempeted Greath	Elongated Growth	Elongated	Creech	Elengated Greeth	Clongated	Elongated Growth	Elongs Led Growth	Elongated Growth	Elongs Led Growth	Elonga ted Growth	
		Compo- eltion	(9·9)	7.C	710N (9.2)	TICN (4.7)	TiCN (4.8)	TiCN (6.7)	T1CN (3.2)	TÍCN (3.6)	TiCN (2.3)	TiCN (5.4)	T1CN (2.6)	71CN (2.5)	TiCN (3.2)	TICN
	Innermost Layer	Crystal Struc- ture	Gramiar	Cramilar	Gramular	Cramilar	Or artal a g	Granutar	Jeimuszo	Granular	Granular	Gramler	Granulae	Granular	Granular	
	or 2	Carre	T1H (0.8)	7 LN (0.4)	71CN (0.7)	Tic- Tik (1.2)	TIN (1.5)	Tin (0.1)	T1C (0.7)	TÎN (0.6)	TÍN 11.0)	TiCN (0.4)	T\$N (0.3)	TIN (0.3)	TÎN (0.5)	TIN-
á	atrate System		٧	۷.	۷	æ	8	υ	3	٥	a	۵	3	W.	4	0
	-		88	98	41	88	88	90	16	92	93	8	9.8	96	9.7	9.6
	8						Coated	Carbide Cutting	Tools of the	Invention	į					_

6	Flank Wear	1	Internaced Cecting	0.53 IChige ingi	0.50 schipp lags					Fallura ofter 4.7 min. des co Fracted ins	Fallure after 9.8 min. des se	ofter 1.3 ofter 1.3 oupping to	Pallure Fallure after 16.3 after 9.7 ain. des te min. des te	an chillings	20.7 nin. Separation	dier 0.1 after 0.1 min. der te	
v	And!	5	or in	0.41 (Chipping)	0.48 (Chilapting)	(Beg dd prod SE'0	Pallure after 15.1 min. due to lapar Asparation	Pallure adter 12.6 ade. des to leges begarreles	Patiture after 7.1 ads. des to lapes paparetion	Pallure after 13.3 ads. dm to lapareties	Pallure after 19.3 adn. due to Origoing	Fellure alter 17.5 mis. due to Chipping	Pallure atter 16.3 als. de te Otippine	fatiure after	Pailure after due to Layer Millingi	fallure fallure after 1.0 after 0.1 ain. due to nin. due to	failure after 3.9 adn. due to
10		Outermost Layer	i i i			Openhar	Grandar		Ocumelar	Oramiae					Creen lag	Granular	Gramias
		ž -	11	11.8 (0.2)		11CH- 11H (0.7)	T5# (0.2)		4% (0.3)	(0.4)					10.2	11N (6.3)	11 to 10 (1.3)
45		Outer Layer	Crystal Brief.	a: 1004	Q: 3004	K: 408	G: 1004	Q. 1001	a. 1001	K: 408	a: 1001	K1404	Q: 100/	Q: 1001	a: 1001	a. 1004	a: 100%
15		2	11	A1203 (3.4)	41203	A1205 (2.2)	A1203	41203	11.11	(0.9)	A1203	A1203	A)203	A1203	A1203	A1203	A1203
		Second Intermediate	To it is	Permilar	Se general de	Or amelas	Or servit a r	er manife r	Or small or	Oranniar	Granular	Or normal a o	Or smaller.	Oremier	Granular	General of	Or serul a c
20 21	1.	ž į ž	j!	11.00 10.11	11(0)	71CHO (0.1)	T1CHO (0.1)	1500 (0.1)	6.2	11CM (0.1)	11CHO (0.1)	TICNO (0.1)	TICHO (0.1)	71CNO (0.1)	10.10	#100 (0.1)	T1CHO (0.2)
TABLE	Hard Coating Layer	First Intermediate Laver	73 j. g.	Ormanies	Gramm Lac	Granitae	Creek lag	Gemelae	Ormstee	Greenlar	Gramitae	Ormalar	Granler	Gramman	Gramiar	Genduses	avenue ao
25	g pr	2 5 3	j.1	ž.č.	71c (2.9)	7.5 (2.5	₽£ (3.5)	1.0 0.0	9.6 9.6	1 . 6 .	#1¢ (2.9)	11.00	710	710	7.c (1.5)	771CN	Tic .
		aye r	Or iont of 100	111111200112201	(220) (200) (1(1)	(111) (2001 (230)	(2001123011313)	(11111294) (326)	(220) (200) (3/1)	(2001) (220)	(311) (200) (220)	12201 (200) (1111)	(1)111(2001(220)	12201120011211	111111200113201	(226) (266) (111)	(1111 (200) (220)
30		Inner Layer	To Sale	Orember	Greenlee	Cramiter	Crambion	Oramiae	Oranilor	Cramelar	Gennutae	Oranulae	Gramalia	Creentles	Oramelar	Oceaniar	Ceanuler
			11	TIC: (6.0)	75.CE	3.5	11.01 13.51	71CH (4.7)	71CW (65)	71CN (3.1)	11.01	7.51 12.51	71C# (5.5)	11CN	11CK	73.CF	11.61
35		Invermost	Crystel Brre-	Oranilar	Orestaler	Or news law	St ente La r	Granular	Granuler	Or eartel by	Granul o r	Oranglar	Creenter	Crawler	Greenlar	Gramise	Beamlee
		- E	11	1 (0.0)	10.4 10.4	71C# 10.5}	#ië- #i# (1.3)	118	7[8 (0.1)	11c (0.0)	71N 10.51	71N (0.9)	71CP (0.5)	# C. 0	10.01	118 10.41	118. 1108
40		i		~	•	4	-		u	v	۵	۵	۵	3	Ŀ	i.	o
				=	=	=	2	2	2	=	26	2	ž	35	96	£	:
		ķ						Conted	Carbide Cutting Tools of	Prior Act					,		
45																	

TABLE 18 (a)

	L	-								Mard Coating Laver	yer but	Į,						
	å																	
97¢	# }		Innermost								Imp	Imer Layer						
			_	2	st Divi	Piest Divided Leyer	1 3	Pirst Dividing	•	Second Divided	Second 2	Second Dividing	Third Di	Third Divided Layer	Talra 2	Taled Dividing Leyer	forth D	Forth Divided Layer
		8 4	Compo- altion Seruc- ture		it is	Crystal Bructure	atrion .	Crystal Struc-	100	Crystal Structure	attlen	Crystal Struc- rure	Compo- altico	Crystal Structure	Campa	Crystal Struc- ture	Compare Compare	Cystal Structure
	6	¥ ::	Tin Granules		TICN (2.4)	Element ad Growth	Tir (0.3)	Craemlar	1.5 2.5 3.6	Elengated Oronth	TIN (0.2)	Greenslar	71CK (2.4)	Elongaced Growth	TLN (0.2)	Cremiter	71CK (2.3)	Elempated Growth
<u></u> -	8	V		FC	TiCN (3.0)	Elongated Growth	T() (0.2)	Oremiler	71CN (3.0)	Elongated Orosch								
<u>-</u>	101	۸ (0.±	Tin Cremier	\vdash	T1CN (3.2)	Elonget ed Growth	TIN (0.2)	Oremaler	T10N (3.1)	Elongated Growth		٠						
	2	A TIN (0.5)	Tin Greenlar	-	TiCN (3.1)	v	TiN (0.2)	Granuler	±10≥ (3.0)	Elongated Growth								
C at a d	6	a		¥ C	TiCN (2.7)	Elongat ed Growth	TIN (0.2)	Cramilar	T10V (2.7)	Elengated Growth	T1N (0.2)	Gremular	TICN (2.6)	Element ad Greath				
1	104	17. T. 17.	Tic- Tin (1.4)	-	71CN (2.2)	Elongated Growth	TIN (0.3)	Oremise -	TiON (2.3)	Elongated Growth								
ut jos	501	a T.T.	Tin Gramles		11CN (3.4)	Elongated Growth	TIN (0.2)	Granular	710v (2.6)	Elongated Growth	TÍN (0.2)	Gramlar	71CN (2.8)	Elongated Growth				
<u>!" </u>	306	v		F E	15CN (4.7)	Elongated Growth	Tin (0.2)	Gramiler	T(C)	Elongated Growth								
-	101	C 7i	Tic (0.5) Granular		11.0v	Elongat ed Growth	71N (0.1)	Greenler	71CV (0.8)	Elongated Growth	TIN (0.2)	Granular	71CN (1.0)	Elongated Growth				
	108	f e	T1N Gramler	_	TiCN (2.5)	Elonget ed Greech	T1N (0.3)	Granuler	710V (2.3)	Elongated Growth	TiN (0.2)	J of Number	TiCN (2.4)	Elongated Growth				
	109	0 ±	TiN Granular		TiCN (3.2)	Elongat ad Growth	T.N.	Óramiler	71CN (3.2)	Elongeted Growth								
	011	τ. (0.1	TIN Gramler		T1CN (1.2)	Flongat ad Growth	T1N (0.2)	Gremler	71CN 13.0)	Elongated Growth								
	c:	0 Ţ	TiCN Granular		TiCN (2.0)	Elongat ed Growth	TÍN (0.3)	Gramler	TÍCN (1.8)	Elongated Growth	TÍN (0.2)	Granular	T1CN (1.9)	Elongat ad Growth	TIN (0.2)	zermyez	11.0N	Elongaced Growth
	rı:	٥	_	£ 5	Ticn (3.6)	Elongeted	TiN (0.2)	Granular	71CM	Elongated								

TABLE 18 (b)

		1				Kard C	Mard Coating Layer) had E				Flank Wear	Wear
ş		itrate page	Inner Layer	Internation	First Intermediate Layer	istera 5	Second Intermediate	Outer Layer	Layer	Oute	Outermost Layer		•
		-	Orientation	1 8	Crystal Browe-	100	Street,	Compo- altion	Crystal	Compa	Crystal Brrsc rure	High-feed Cutting	Deep-cut Cutting
	ŝ	<	(111) (220) (2001			Ticho (0.1)	Gramler	A1203	K: 941	TIN (0.2)	Granular	0.15	0.15
_	8	<	(220) (111) (200)	3.0 (3.0)	Granular	TiCN0	Gramilar	A1203	K: 1004	TIN (0.2)	Cremiler	0.16	0.20
	19	4	(111) (220) (200)	1.9)	Granuler			A1203	K:1004	TICH- TIN (0.6)	Grandler	0.17	0.18
	ē.	<	(111) (200) (220)	3.0)	Grenular			A1203	K1738	TIN (0.2)	Gramulae	0.21	0.19
Coated	ē	a	(111) (220) (200)			41.0 (0.1)	Gramular	A1203	K: 1004			0.16	0.22
Cartific	ğ	a	(111) (2001 (220)	7.(c	Cramilar	TiCNO (0.1)	Gramular	A1203	K:738	T1N (0.2)	Cramilar	0.15	6.17
inentis	501	6	(111) (220) (200)			4.0 6.1	Granular	A1203	K: 554			0.20	0.16
	ž	v	(220) (111) (200)			1100 (0.1)	Gramlar	A1203	K: 854	TÍN (0.2)	Oresuler	0.20	0.21
	101	v	(220) (200) (1111)	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Granules	TiCNO (0.1)	Grambar	A1203	K: 621			0.24	0.20
	8 0.1	u	(1111) (220) (200)					A1203	K:941	TiN (0.5)	Gressules	0.19	0.23
	109	۵	(111) (220) (111)			T1CNO (0.1)	Granular	A1203	K:731			0.15	0.17
	2	۵	(330) [111] (300)	TICN (1.4)	Granular			A1203	K: 621			0.15	0.22
	111	۵	(111) (220) (200)					A1203	K: 1001			0.16	0.19
	2	۵	(111) (220) (200)	1. 1. 2. 1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.	Granular			A1203	K:738	TLN (0,2)	Gramular	0.16	0.17

TABLE 19 (a)

ž.	4 2 4		Innermost. Layer	Pirat P	Piret Devided Layer	1 2 m	Piese Dividing	2 2	Hard Coating Layer Inner L Second Divided Second Div Layer Layer	ing tay	ng Layer Imar Layer Second Dividing	Third bi	Third Divided Layer	Files 1	third bividing	Porth 9	Porth Divided Layer
		attlen attlen	Crystal Street	attle	Crystal Structure		Crystal - Strue- ture	Composite in	Crystal Structure	eltien	Crystal Strue- rure	Compe	Crystal Structure	elt los	Crystal R.ruc- ture	a tri m	Crystal Structure
_	<u>.</u> n	TÍN (0.4)	Granulas	TICN (1.6)	Elempated Crosch	TÍN (0.2)	Greenler	TiC#	Elempated Oresith							2.5 2.5	Elangated Graves
<u>. </u>	11	TLC# (1.0)	Oremular	TiCH (0.9)	Elumpsted Greath	TIN (0.1)	Organisar	71CH	Elongeted Growth								
Ľ	311			TiCN (1.9)	Elongated Crowth	TÍN (0.2)	Cremiler	TICN (2.0)	Slongeted Greath	TÍN (0.3)	Gramlar	71CN (1.9)	Elorgated Growth				
Ľ	911			71CN (2.2)	Elongat ad Growth	TÍN (0.3)	Or setular	TiCN (2.3)	Stongered Growth								
Control	111	71.0. 71.0.	Oceaniter	Ticn (1.1)	~	TÍN (0.2)	Otenulas	71CN (1.1)	Element ad Greath	Tin (0.1)	Granular	TLCN (1.0)	Elongated Orosch		į		
Curbide Cutting	9			7iCN (3.4)	Plangated Growth	75N (0.2)	Oreneler	T1CN (3.3)	Elongeted								i
<u> </u>	911	TiN (0.5)	Gramilar	71CN (1.1)	Elongated Greech	T1N (0.1)	Granular	71C% (0.8)	El enga ted Growth	TIN (0.2)	Granulas	Tich (1.0)	Elengated Oroseh				
	0 023			TiON (1.7)	Elemented Greech	T'ÉN (0.2)	Gressular	71CN (1.6)	El ongs ted Oreseth								
Ľ	2 121			11CN (2.2)	Elongsted Growth	TIN (0.2)	Grember	71CN (2.0)	El onga ted Growth								
<u>. </u>	8 171	T-1CN (0.6)	Cramiar	71CN (0.7)	Elongeted Orowth	TIN (0.2)	Gramuler	71CM (0.6)	Elempated Greath	TIN (0.2)	Granular	T1CH (0.6)	Elongated	(0.2)	Granular	7.00 (0.2)	Elempated Growth
	133 E	(0.3)	Gramiler	T1CH (1.3)	Elongated Greeth	TIN (0.1)	Oraniar	1104	Elonget ed Growth								
	124 6	(0.3)	Granulae	TiCH (1.8)	Elongeted Growth	TiN (0.1)	Granuler	TLCN (1.7)	Elongated Growth								
<u> </u>	135 E			TICN (1.4)	Elongated Growth	TÍN (0.3)	Granular	TICN (1.3)	Elengated Growth					·			
-	921	E. Tic	Tic Gramler	TICN	Elongated	TÍN (0.2)	Cranular	11CN	Elengated								

TABLE 19 (b)

						Fard	Hard Coating Leyer	ıyer				177	al set tiese
		ģ											1
		strate Symbol	rener Leyer	Pi Intern	Pirst Intermediate Layer	Sec Intern	Second Intermediate Layer	Outer Layer	Layer	Oute	Outermost Layer	5	(mm)
			Or i entation	Campo it for	Crystal Struc-	Campo- sition	Crystal Rirac-	Omer	Crysta.l Structure	came	Crystal Burse-	Continueus Conting	Cutting Cutting
	111	•	(220) (111) (200)	₹ ?	Granular	41.6 6.1.	Granular	A1203	E: 100¢	TÎN (0.2)	Gremler	0.14	0.18
	777	5.	(111) (220) (200)			71CNO (0.2)	Granular	A3203	K:941	TIN (0.2)	Oranu]ar	0.12	0.19
	1118		(111) (220) (200)	3 f.	Oremeler			A1203	K: 1004			6.13	0.25
	¥.		(111) (200) (220)					A1203	K1948	#£8 (0.0)	Cramiler	0.14	0.21
Control	ii.	U	(111) (220) (200)			51.0 0.1	Granular	A1203	K: 551			0.12	0.20
Carbide Cutting Tools of	i	U	(220) (111) (200)			7100 (0.1)	Granular	A1203	K1941	5 (0 . 4	Granular	0.11	0.24
the Invention	â	u	(220) (200) (111)	718 (1.7)	Gramuler			A1203	K: 621	TIN (0.5)	Oremeler	0.15	0.20
	82	u	(111) (230) (200)	7.5 (2.9)	Oranular	71CNO (0.1)	Gramular	A1203	K:854			0.14	0.19
	111	o .	(220) (111) (200)					A1203	K: 1004			0.12	0.23
	133	8	(332) (322) (111)					A1203	K:948	T\$N (0.3)	Gramular	0.14	(M1111ng)
	621	a a	(220) (111) (200)	7.tc	Gramiat	11CM (0.1)	Grenular	A1203	K: 1001			0.15 (1	(Milling)
	134	20	(311) (230) (200)			71CM (0.1)	Granular	A1203	K: 1001	TÎN (0.2)	Granular	0.14	(MIIIIng)
_	125	63	(326) (111) (326)	71C2 (0.8)	Granular			A1203	K: 1004			0.15 (1	(Milling)
	72.	ü	(331) (220) (200)			Ticko	Gramiler	A1203	K: 944	11N	Oremular	0.14	(Milling)

TABLE 20

															_	
Wear	n)		0.53 (Chipping)	0.52 (Chipping)	0.43 (Chipping)	0.57 (Chipping)	0.60 (Chipping)	0.39 (Chipping)	Failure after 21.6 min. due to Layer Separation	Fallure after 20.8 min. due to Layer Reparation	Pailure effer 9.0 min. due to Layer Esperation	Fallure after 20.8 min. due to Layer Separation	0.54 (Chipping)	Pailure after 3.6 mdn. due to Frecturing	Pailure after 5.9 ain. due to Fracturing	Fallure after 6.5 mln. dur
Plank Weer	(max)		0.57 (Chipping)	0.61 (Chipping)	0.59 (Chipping)	0 . 60 (Chipping)	0 . 64 (Chipping)	0.59 (Chipping)	Pailure after 21.6 min. due te Leper Separation	Failure after 19.5 min. due to Layer Separation	Failure after 15.1 ain. due to Leyer Seperation	Pailure after 19.5 min. due te Leyer Seperation	0.59 (Chipping)	Fallure after 13.9 min. due to Chipping	Pallure after 12.4 min. due to Chipping	Failure after 11.5 min. due
	Outermost Layer	Crystal Struc- ture	Granulas	Gramuler	au pasuago	Granules	•	Granulae		Oranu lar		Granular				Gramular
	Out.	Compo- sition	TIN (0.2)	TiN (0.2)	TiCN- TiN (0.6)	TÍN (0.3)		T1N (0.3)		TÍN (0.2)		TÍN (0.5)				TÍN (0.3)
	Outer Leyer	Crystal Struc- ture	a:1001	a:1001	K: 401	G:1001	a:1001	a:1001	a:100%	a:1004	K: 408	a: 100%	G: 1004	\$00t:D	1001 a	a:1004
	Outer	Compo- attien	A1203	A1203	A1203	A1203	().()	A1203 (2.1)	A1203 (3.2)	A1203 (1.6)	A1203 (0.9)	A1203 (2.5)	A1203	A1203 (8.0)	A1203 (2.9)	£0214
	Second Intermediate Layer	Crystal Struc- ture	Greenler	Oremuler			Oremiler	Gramilar	Cremine	Oremler	Oranular		Grambar			
1	Inter	como	T1CN0 (0.1)	71CM (0.1)			71CO (0.1)	TiCRO (0.1)	71C0 (0.1)	71C0 (0.1)	TiCNO (0.1)		11CM (0.1)			
Hard Coating Layer	Pirst Intermediate Layer	Crystal Struc-		Gramular	Qraffallar	Granular		Granular			Oranular			Oremiler		Cremiar
lard Cos	Pi Intern	cano est lan		T1C (2.8)	71C (2.0)	71c (3.0)		71C (3.6)			TLN (1.8)			T.LCN (1.2)		TIC (1.3)
		Orientation	(1111) (200) (220)	(220) (200) (221)	(111) (200) (111)	(2001 (220) (311)	(111) (100) (110)	(220) (300) (111)	(200) (320) (311)	(111) (200) (111)	(220) (300) (311)	(227) (200) (220)	(220) (200) (177)	(111) (300) (111)	(211) (002) (022)	(022) (002) (111)
	Inner Layer	Crystal Func-	Grandlar	Orace) as	Granular	Orenvlar	Gramler	Granular	Cranular	Ormuler	Oramler	Orember	Granulas	Ocemular	Gramiles	Granular
		eitim	1.5 3.5	#10 (6.1)	1.0 3.30	710v (6.0)	₽ 1 0	710v (6.6)	T.CN (8.7)	71CN (9.8)	7.(CN (2.5)	T4CN (7.7)	71CN (6.3)	7.CN (2.4)	Tick (8.2)	Tick (6.9)
	Innermost Løyer	Crystal Strue- rure	Crumalas		Granules	Granulae		Gramlar	Cranular		Gramilar	Oremuler	Cremiler	Geamler	Gremuler	L
	rg Z	STEE STEE	11N (1.0)		7;N (0.6)	45K (0.5)		750- 75N (1.5)	TEN (1.7)		11C	11N (0.5)	1 (0.6)	Tin (0.7)	TICN (0.5)	
Ž	Symbol Symbol		4	4	4	۲	•	4	•	υ	U	U	۵	۵	۵	۵
			2	8	101	102	COT	101	105	7 01	691	100	6 1	911	11	2
	\$							Coated Communication Carbide	Tools of Prior Art							

		Mear	ia.	Interruped cutting	Fallure after 0.0 sin. das to Frequeing				Pailure after 5.8 min. due to Procturing	Pailure after 4.5 min. due to Practuring	Failure efter 7.4 als. due to Frecturing		Failure efter 5.2 min. Oue to Fracturing	l (Chipping) (Milling)	0.37 (Chipping) (Hilling)	0.33 (Chipping) (Hilling)	0.38 (Chipping) (Milling)	hipping) ling)
6		Plank Wear	(may)	Centimens Cetting	Pailure after 13.6 min. due to Chipping	Pailure after 16.0 pin. due to Chipping	Pailure after 14.4 min. due te layer Separation	Pallure after 15.1 min. due to Layer Separation	Pailure after 17.4 pin. due te Chipping	Failure efter 16.3 min. due to Layer Beparation	Pailure after 12.5 min. Oue to Chipping	Failure after 13.3 min. due to Leyer Separation	Pailure after 17.6 min. Oue to Layer Separation	O.41 (Chipping) (Milling)	0.37 (C (MS1	0.33 (C (M1)	0.38 (C (M1)	0.36 (Chipping) (Milling)
10			Outermost Layer	Crystal Street	şalı	Greenlar		Granular		Ozamular	Greenlar			Cramalar		Granuler		Gramiter
			ğ	altipa ettipa	T138 (0.2)	TIN (0.2)		11H (0.3)		75N (0.4)	TÚN (0.5)			Tin (0.3)		TIN (0.2)		TIN (0.2)
15			Outer Leyer	Cystal Pare:	a:1001	a:1001	K: 401	a:1001	a:100f	a:100¢	10P:X	a:100s	K: 408	a:1001	a:1001	a: 100%	a:1004	a: 1001
			Outer	87.7	A1203	A1203 (0.7)	A1203 (1.5)	A1203	A1203 (0.5)	A1203 (2.0)	A1203 (0.8)	A1203 (1.2)	A1203 (1.0)	(8'0)	A1203	A1203	10,11	41203
20			Second Intermediate	Chystal Strue:	Orwales	Oremules			Oreputhas	Crambar		Cramlar			Granular	Granular		Cranular
			In Sec.	100	5.5	T1CHO (0.2)			7100 (0.1)	71C0 (0.1)		Ticro (0.1)			71CNO (0.1)	T(CNO		T1CN0
25	TABLE 21	Hard Coating Layer	First Intermediate	Tana Cara	Or ermiler		Grenular				Craracter	Gramulag			Grenular		Granular	
	T.	20	Inter	S C C C C C C C C C C C C C C C C C C C	5 S		71CK (1.2)				Tin (1.8)	T1C (2.8)			Tic (1.5)		71CN (0.9)	
30		±	ayer	Orlandation	(113) (200) (210)	(220) (200) (111)	(111) (300) (220)	(200) (320) (111)	(111) (200) (220)	(111) (300) (311)	(200) (330) (331)	(311) (300) (111)	(111) (2001) (022)	(111) (200) (220)	(220) (200) (111)	(111) (200) (111)	(111) (002) (022)	(111) (200) (210)
35			Inner Layer	12 cyane	Cr emuler	Oremulae	Greenlar	Orasm) ar	Gramilar	Granular	Cremiter	Gramular	Gramlar	Granular	Granular	Gramilar	Cramler	Granular
36				1 5	11CN 5.2	11.2 (2.1)	7.CV (6.5)	71CV (4.6)	T1CH (3.5)	TiCN (7.0)	7.CV	T1CN (3.3)	T.CN (4.5)	71CN	7iCN (2.6)	£ € .s.	14 C	71CN
			Innermost	Crystal Brruc	Oremalaer	Or actual as			Granuler		Crambar			Greenlar	Granular	Granules		Gremiar
40	•		ig 3	100	¥ .0	- NICE			-71C -71K		1 (0.6)			71CM	TIN (0.3)	7 tiv		714 (0.8)
			iii	•	-				0	u		ıs	o			۵	à	.3
45					3.	ä	1	ă	3	2	2	ă	ĕ	ã	ŝ	12	521	*
			ę.							Control Corbide Octifie	Thols of Price Art							

Claims

50

1. A coated hard alloy blade member comprising a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, characterized in that said hard coating includes an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al₂O₃ having a crystal form x or x + α wherein x > α.

- A coated hard alloy blade member according to claim 1, wherein the TiCN in said elongated crystals of said inner layer has X-ray diffraction peaks such that strength at (200) plane is weak compared to strengths at (111) and (220) planes.
- 5 3. A coated hard alloy blade member according to claim 1 or claim 2, wherein said hard coating further includes an innermost layer of one or more of granular TiN, TiC, or TiCN formed underneath said inner layer.
- 4. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes an outermost layer of one or both of granular TiN or TiCN formed on said outer layer of Al₂O₃.
- 6. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes a first intermediate layer of one or more of granular TiC, TiN, or TiCN formed between said inner layer of TiCN and said outer layer of Al₂O₃.
 - 6. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes a second intermediate layer of one or both of TiCO or TiCNO formed between said inner layer of TiCN and said outer layer of Al₂O₃.
- 7. A coated hard alloy blade member according to any one of the preceding claims, wherein said inner layer of TiCN further includes one or more layers of TiN such that the inner layer is divided by the layers of TiN.
- 25 8. A coated hard alloy blade member according to any one of the preceding claims, wherein said WC-based cemented carbide consists essentially of 4 12 % by weight of Co, 0 7 % by weight of Ti, 0 7 % by weight of Ta, 0 4 % by weight of Nb, 0 2 % by weight of Cr, 0 1 % by weight of N, and balance W and C.
- 9. A coated hard alloy blade member according to claim 8, wherein the maximum amount of Co in a surface layer of the substrate ranging up to 100 μm depth from a surface thereof is 1.5 to 5 times as much as the amount of Co in an interior 1 mm deep from the surface.
- 10. A coated hard alloy blade member according to any one of the preceding claims, wherein said TiCN-based cermet consists essentially of 2 14 % by weight of Co, 2 12 % by weight of Ni, 2 20 % by weight of Ta, 0.1 10 % by weight of Nb, 5 30 % by weight of W, 5 20 % by weight of Mo, 2 8 % by weight of N, optionally no greater than 5 % by weight of at least one of Cr, V, Zr or Hf, and balance Ti and C.
- 40 11. A coated hard alloy blade member according to claim 10, wherein hardness in a surface layer of the substrate ranging up to 100 µm depth from a surface thereof is more than 5% harder than hardness of an interior 1 mm deep from the surface.
 - 12. The use of a hard coated blade member according to any one of the preceding claims in cutting tools.

50

45

15

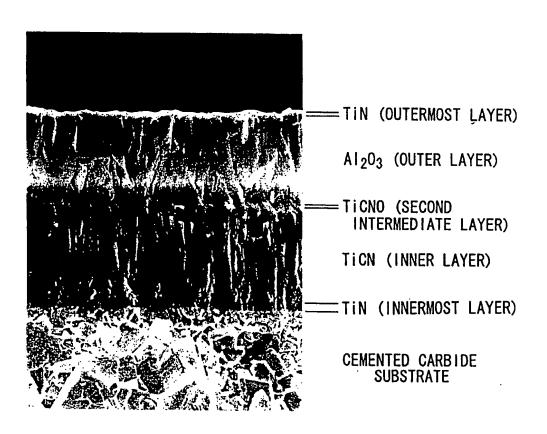


FIG. 1 COATED CEMENTED CARBIDE CUTTING TOOL "64"